LINKING DECISION SUPPORT SYSTEMS FOR DUCKS WITH RELATIVE ABUNDANCE OF OTHER GRASSLAND BIRD SPECIES

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By

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ABSTRACT

Decision support systems (DSS) that integrate long-term duck population and land use data are currently being used to develop conservation programs on the Canadian prairies. However, understanding inter-relationships between ducks and other grassland bird species would greatly enhance program planning and delivery among various bird conservation initiatives. Therefore, to achieve these goals, grassland bird species richness and relative abundance were compared between areas of low, moderate and high predicted waterfowl breeding densities (strata) in the southern Missouri Coteau, Saskatchewan. Roadside point counts were conducted during spring 2001 and 2002, and habitats were delineated within 400 m radius of each point.

More birds of more species were encountered in the high density waterfowl stratum when compared with low but species that tended to co-occur with ducks were primarily wetland-associated. Overall, duck and other grassland bird species richness and abundance were moderately correlated ($0.69 > r > 0.37$, all $Ps < 0.05$); strong positive correlations between priority species of conservation concern and northern pintails were not found. No difference in mean number of priority grassland species occurred among strata, but differences were found for both number of species and total birds detected among routes within strata. High duck density stratum was more heterogeneous, consisting of greater areas of forage, shrub, wetlands, and open water bodies whereas low stratum contained larger, more uniformly-shaped habitat patches and greater proportion of cropland.

Ordination analyses revealed that most priority species occurred in grassland-dominated sites with lower shrub area and wetland density whereas most wetland-associated species, including ducks and 2 priority species (Wilson's phalarope and marbled godwit) inhabited cultivated areas with higher wetland density. Ducks and priority species generally did not co-occur at the stop-level in highly heterogeneous landscapes but suitable habitats for both groups may exist in near proximity. In homogeneous landscapes, ducks and other wetland-associated common species were less abundant because of limited number of suitable wetlands. To achieve these dual goals, conservation efforts should be focused in areas containing wetlands adjacent to contiguous tracts of native pasture.

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DEDICATION

To my late grandmother, Mary Helliwell who first introduced me to the wonderful world of birding. Her love of all birds, especially owls and quail, inspired me to learn more about these remarkable creatures. She grew up in southern Saskatchewan in the 1930s and I often thought of her while I stood watching and listening to the birds during my early morning surveys and wondered what it must have sounded like in her time. I think she would have enjoyed those mornings with me.

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CHAPTER 1. GENERAL INTRODUCTION

1.1 Declines in grassland bird populations

Many North American grassland birds are declining at a greater rate than avifauna associated with other habitats, even though many share common wintering areas (Samson and Knopf 1994, Herkert 1995, Peterjohn and Sauer 1999, Downes et al. 2003). Grassland birds are species adapted to or reliant on grassland habitats during breeding, migration or wintering periods (Vickery et al. 1999). Canadian Breeding Bird Survey (BBS) trend data indicate that grassland bird populations in Bird Conservation Region (BCR) 11 (Prairie Pothole Region in Alberta, Saskatchewan and Manitoba and north central US) declined at an average rate of 1.5% per year since 1969 (Downes et al. 2003; Figure 1.1), and have experienced even steeper declines within the last 10 years (- 2.5 % per year). More specifically, Baird's sparrow (*Ammodramus bairdii*), chestnut collared longspur (*Calcarius ornatus*), and Le Conte's sparrow (*Ammodramus leconteii)* have declined at rates over 9 % per year since 1993 (Downes et al. 2003; Figure 1.2). Since the breeding ranges of many grassland species are restricted to this region (i.e., endemic; Mengel 1970), these long-term population declines have been attributed to loss, fragmentation and degradation of natural grassland habitats due to agricultural practices (Samson and Knoph 1994, Houston and Schmutz 1999, Vickery et al. 1999, Smith and Radenbaugh 2000).

Historically, native grasslands dominated the Saskatchewan Prairie region (Smith and Radenbaugh, 2000). Over the last 100 years, native prairie habitat has undergone a dramatic decline due to agricultural practices. To date, 93% of the prairie ecozone has been lost or altered and only an estimated 20% of native habitats in the mixed grass ecoregion remain (Epp 1992, Neave and Neave 1998). In addition, regional studies estimate between 50 and 70 percent of wetlands on the Canadian prairie have been drained or cultivated (Epp 1992, Neave and Neave 1998). Rate of loss in these ecologically significant areas is also a concern. From 1971 to 1996, grassland and

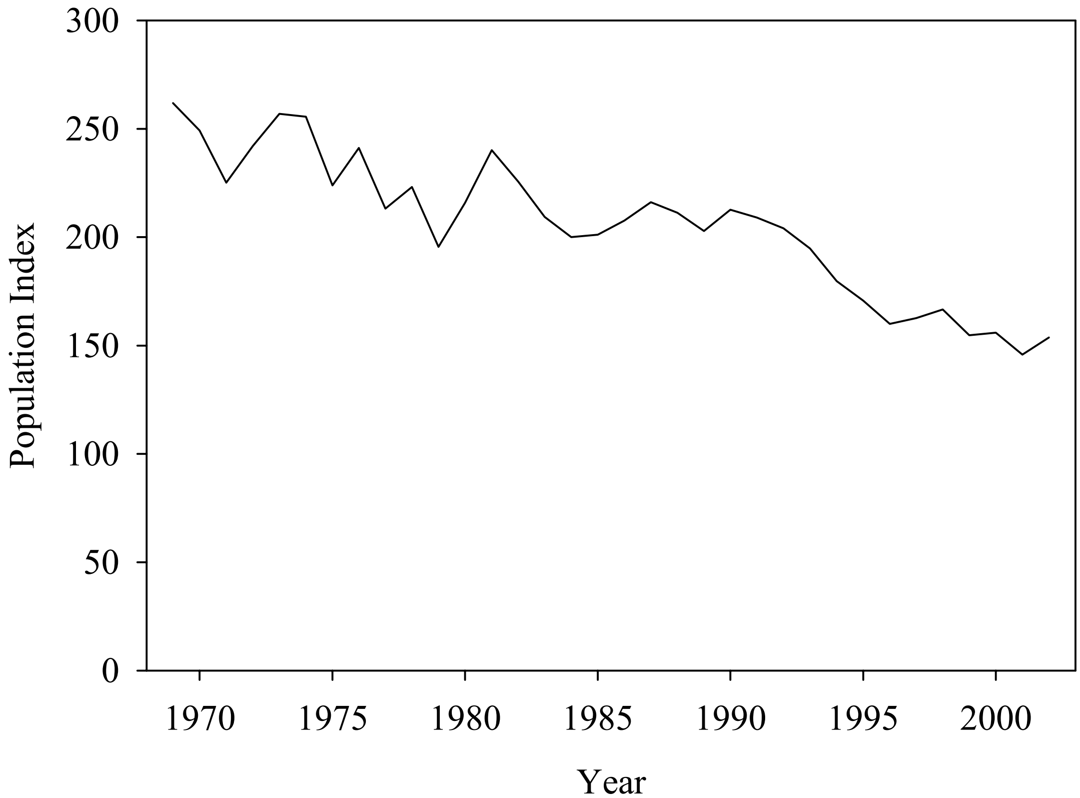


Figure 1.1. Population index for the grassland bird group (n = 20 species) in Bird Conservation Region (BCR) 11 in prairie Canada based on annual Breeding Bird Surveys (BBS) across North America since 1968 (Downes et al. 2003).

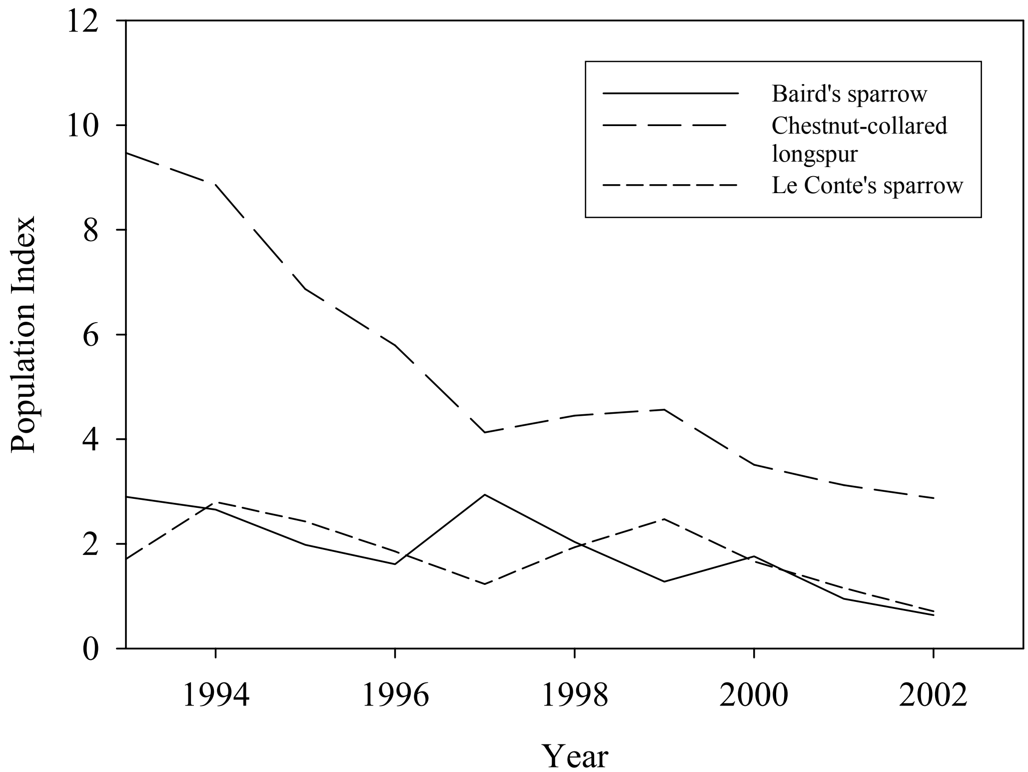


Figure 1.2. Population indices of 3 grassland bird species: Baird’s sparrow (*Ammodramus bairdii*), chestnut-collared longspur (*Calcarius ornatus*), and Le Conte’s sparrow (*Ammodramus leconteii*) in BCR 11 in prairie Canada (Downes et al. 2003) from 1993-2002 based on annual Breeding Bird Surveys (BBS) across North America since 1968.

parkland ecoregions lost more than 2.4 million ha of natural lands, an annual loss of 146,000 ha (DUC 2000). Furthermore, approximately 650 ha of native grassland within key waterfowl producing areas in the Missouri Coteau is destroyed annually (DUC 2000). Although rate of loss has decreased in recent years, remnant prairie fragments continue to be degraded by either exotic species, and woody encroachment (i.e., trees or shrubs) or the arrest of natural processes such as fire or grazing (DUC 2000, Smith and Radenbaugh, 2000). Other possible causes of decline include pesticide and herbicide use, increased continuous cropping practices, fire control and the elimination of bison and prairie dogs (Houston and Schmutz 1999, Smith and Radenbaugh, 2000, Prodruzny et al. 2002).

The North American Waterfowl Management Plan (NAWMP) was established in 1986 and evaluation of the impact of the Prairie Habitat Joint Venture (PHJV) programs on non-waterfowl species was initially stated as a priority (NAWMP 1986). Recent NAWMP updates emphasized biodiversity conservation by stating that enhanced landscape conservation coordination with other wildlife agencies will be directed at other migratory birds, endangered species, fish, and amphibians (NAWMP 1998, 2003). Although intensive programs were created primarily for waterfowl, habitat securement and enhancement has the potential to yield significant benefits to other wildlife species including other grassland birds (Hartley 1994, Anderson et al. 1995, Prescott and Murphy 1999).

Currently, decision support systems (DSS) such as the Predicted Waterfowl Breeding Distribution and the Saskatchewan Digital Land Cover map products aid waterfowl managers to develop conservation programs in areas of greatest waterfowl potential. However, a similar large-scale DSS approach has not been used for conservation of other grassland bird species (Madden et al. 2000, Niemuth 2003, Davis 2003). As many populations of these species are currently declining throughout the prairie pothole region, it is essential to determine the extent to which habitat planning and activity in areas of high priority for ducks contribute to habitat and conservation goals for other grassland species of concern. To evaluate the relationships of waterfowl with other grassland bird species, habitat features correlated with the distribution and abundance of priority grassland bird species must first be identified.

Duck species may act as an umbrella or indicator group whereby conservation of key duck habitat will protect and enhance habitat needed by other grassland birds (Landres et al. 1988, Simberloff 1998, Lawlers et al. 2003). Duck breeding area requirements vastly exceed area needs of most other grassland bird species and typically include a broad array of wetland types and upland cover for foraging, pairing, nesting habitat, and brood rearing habitats of many wetland-associated and upland bird species (Greenwood et al. 1995, Williams et al. 1999, Mack 2003). Therefore, ducks and grassland bird species (i.e., shorebirds and landbirds) that share common habitats (e.g., wetlands, native pastures and shrubs) may be affected in similar ways by processes such as habitat loss and fragmentation, producing covariation in patterns of bird abundance (Johnson 1996).

As such, areas of high waterfowl density may reflect greatest habitat diversity and quality nesting habitat that may also benefit multiple bird species. In contrast, low duck density areas may have limited suitable wetland or upland breeding habitats for ducks and other non-waterfowl species. For example, bird abundance, diversity and productivity is lower in cultivated cropland than in native habitats (Hartley 1994, Davis and Duncan 1999). In some cases, duck density may not be a reliable indicator of landbird abundance or species richness. Cultivated areas with high wetland density (a good predictor of ducks) may support greater numbers of over-water nesting duck species (e.g., canvasback [*Aythya valisineria*], redhead [*Aythya americana*] and ruddy duck [*Oxyura jamaicensis*]; Krasowski and Nudds 1989, Maxson and Riggs 1996) but may be void of suitable upland nesting habitat for other grassland birds. Additionally some grassland obligates (i.e., species exclusively adapted to grassland habitats; Vickery et al. 1999) such as Sprague's pipit or Baird's sparrow may be area sensitive and require large expanses of native prairie where ducks may not be common (Johnson and Igl 2001, Davis 2003).

Although many studies suggest that variation in grassland bird species richness and abundance can be attributed to fine-scale vegetation characteristics, patch and surrounding landscape features are now thought to be important determinates of breeding grassland bird distribution and reproductive success (Clark and Diamond 1993, Hartley 1994, Herkert and Knopf 1998, Davis et al. 1999, Sovada et al. 2000, Bakker et al. 2002). This study did not directly assess grassland bird productivity, but it may identify landscape-level habitat features that significantly influence grassland bird abundance. These bird-habitat patterns may provide insight into causes of population declines and could help to guide management decisions and conservation strategies for multiple species (Hejl and Granillo 1998, Madden et al. 2000). Bird abundance and landscape level habitat (composition and configuration) data were collected in areas of widely varying predicted waterfowl densities to evaluate relationships between landscape level habitat features common to both ducks and other breeding bird species in BCR 11. Understanding the extent to which ducks and other grassland birds co-occur can help target areas for conservation activities and integrate planning among various bird conservation initiatives.

1.2 Thesis objectives and format

Specific objectives were to (1) determine whether relative abundance and species richness of grassland birds are correlated with predicted waterfowl breeding density derived from DSS and (2) identify habitat attributes that are correlated with grassland bird species richness and relative abundance, with emphasis on grassland species of special conservation concern. Chapter 2 describes the study area and general methods used in subsequent chapters. In chapter 3, I investigate whether predicted waterfowl density, based on an existing model, reliably indicates breeding habitat suitability for other grassland bird species. I describe grassland bird community composition and abundance in relation to landscape level habitat characteristics among areas of differing predicted duck densities. I also evaluate whether ducks could be considered "umbrella" taxa for other grassland birds, using abundance and richness data (Simberloff 1998, Suter et al. 2001). In chapter 4, ordination techniques were used to describe broad structure at the bird community scale and evaluate landscape features common to both waterfowl and other grassland bird species. Avifaunal richness and abundance may increase with habitat patch size and diversity of habitat features. Natural areas (e.g., native grasslands, wetlands, shrubs) provide greater complexity of plant species, food sources and habitat types than modified habitats (e.g., grain or oil seed crops) thus providing habitat niches for a greater diversity of bird species, including waterfowl.

Chapter 5 is a synthesis of main conclusions and a discussion of study limitations, management implications and suggestions for future research.

I also present supporting data and analyses for the main chapters in Appendix A, assessing major assumptions and limitations of bird detection and effects on estimates of relative abundance (relevant to habitat association analyses). Appendix B consists of supplemental tables and figures for the main data chapters.

CHAPTER 2. STUDY AREA AND GENERAL METHODS

2.1 Study area

Work was conducted approximately 100 km south of Regina, Saskatchewan, within the southeastern portion of Missouri Coteau, south central Saskatchewan (Figure 2.1). The area is between the Moist-mixed and Mixed Grassland ecoregions of the Prairie ecozone (Acton et al. 1998) and includes a wide range of predicted waterfowl breeding densities (i.e., from < 8 to > 40 pairs/km^2). The study area was within a 72 km radius centered on Ceylon (49º 23' N, 104º 39' W) and encompassed approximately 16,500 km^2 within 5 landscape areas (Trossachs and Regina Plains, Coteau Lakes Upland, Lake Alma Uplands and Wood Mountain Plateau; Acton et al. 1998). Elevation across the study area ranges from 600-1000 m above sea level and Brown to Dark Brown soils formed in glacial till deposits predominate. Most of the area is cropland (65%); cereals are the major crop and approximately 30-40% of the cropland area is summerfallow (Acton et al. 1998). Native grassland (23%), water-bodies (5%), and low percentages of tame pasture, shrubs, trees, and farmlands make up the remaining area. The Western Hemisphere Shorebird Reserve Network, and BirdLife Canada along with Canadian Nature Federation recognize this area as critical habitat for 2 species at risk: burrowing owl (*Athene cunicularia*) and piping plover (*Charadrius melodus*), as well as for waterfowl, many other grassland birds including some shorebirds and colonial nesters such as American white pelican (*Pelecanus erythrorhynchos*).

The rolling terrain of the Missouri Coteau holds nutrient rich wetland complexes as well as remnant native grasslands. Wheatgrasses (*Elymus spp*.), June grass (*Koeleria cristata*) and needle grasses (*Stipa spp*.) are typical of both upland Mixed and Moist-mixed Grasslands and blue gramma (*Bouteloua gracilis*) is common in drier areas. Invasive species such as smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) are also common. Shrubs are limited to moist depressions or to drier wetland

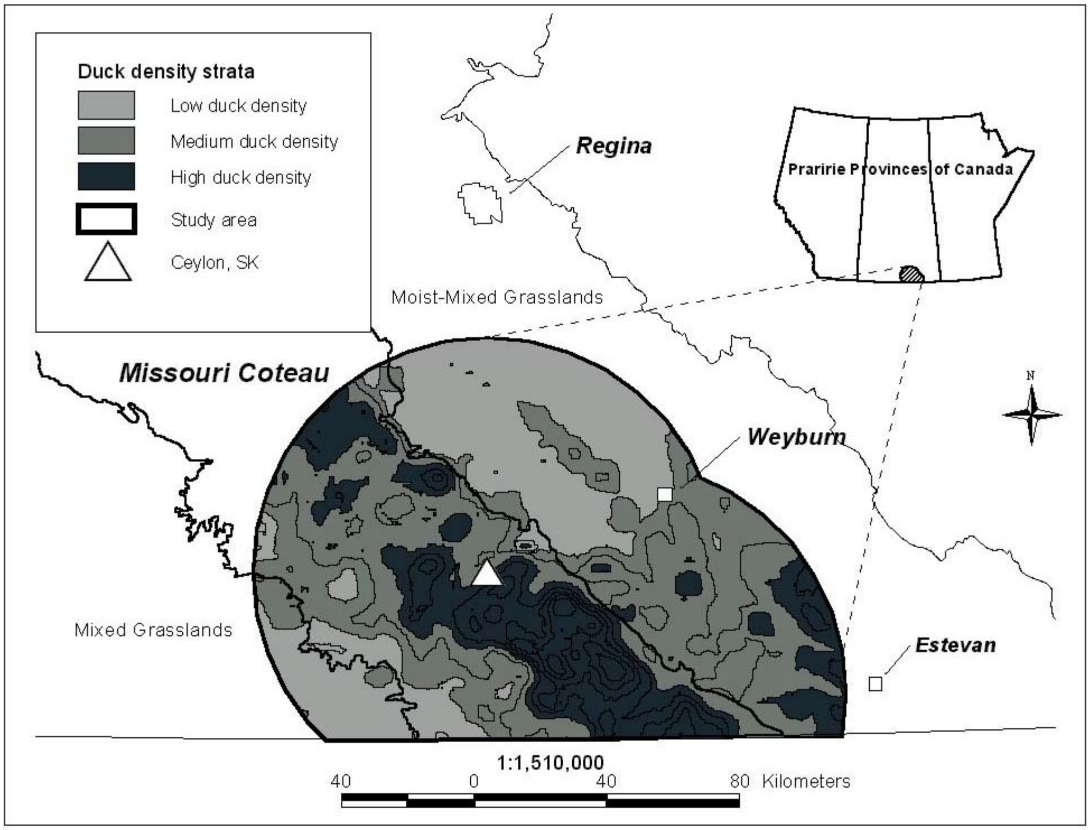


Figure 2.1. Location of study area within the southeastern portion of the Missouri Coteau in southern Saskatchewan, Canada. Predicted waterfowl breeding density strata [low (< 8 duck pairs/ km^2), medium (> 8 to < 15 pairs/ km^2) and high (> 15 pairs/ km^2)] are shown in colour.

margins. Dominant shrub species include western snowberry (*Symphoricapos occidentalis*), wolf-willow (*Elaeagnus commutata*), and willow (*Salix* spp.). Aspen (*Populus tremuloides*) is the most prevalent tree species in the area. Common wetland vegetation ranges from wet-meadow grasses such as marsh reed grass (*Calamagrostis canadensis*) and Baltic rush (*Juncus balticus*) to shallow marsh vegetation such as reed canary grass (*Phalaris arundinacea*) and whitetop (*Scolochloa festucacea*). Aquatic emergents include bulrushes (*Scirpus spp*.) and cattails (*Typha latifolia*). Salt-tolerant plants such as Nuttal's alkali grass (*Puccinellia nuttliana*) and red samphire (*Salicornia rubra*) are associated with saline wetlands.

2.2 General methods

2.2.1 Decision Support Systems (DSS)

I used 2 digital Decision Support System (DSS) map products during data collection and analyses. First, I used the South Saskatchewan Digital Land Cover map product for analyses of landscape-level habitat characteristics (DUC and IWWR 1999a; Table 2.1). Saskatchewan Research Council (SRC) and the Prairie Farm Rehabilitation Administration derived ten land cover classes from digitally classified Landsat Thematic Mapper (TM)- 7 satellite images (Polson and Mactavish.1994; Table 2.1). TM has 7 spectral bands (3 in the visible spectrum, 1 near-infrared, 2 mid-infrared and 1 thermal infrared band) and satellite sensors record electromagnetic spectral reflectance of ground features. Contrasts in spectral responses discriminate between water, mineral, soil and vegetation characteristics with a minimal digital resolution of 30 m x 30 m (Knick and Rotenberry 1995, Johnson 1998). Satellite imagery for southern Saskatchewan was collected from October 1993 to June 1995 and the accuracy of correctly classifying native dominant grasslands was assessed between 80%-100% with an average of 94%; pastureland was estimated to be 80%-100% accurate with an average of 93.7% accuracy (SRC 1999).

Digital land cover information along all survey routes was verified and manually updated during visits to all stop points in each year. Corrections were documented directly on field diagrams and with digital photographs. GIS-based land cover editing

Table 2.1 Descriptions of 10 South Saskatchewan Digital Land Cover classes derived from Landsat imagery (1993-1995) and used to assess habitat use patterns by grassland birds in Southern Saskatchewan, 2001 and 2002 (DUC and IWWR 1999a)

Land cover classes	Description
Cropland	Land that is seeded annually to cereal, oil seed and other specialty crops; or is in summer fallow.
Forage	Land that is perennial forage for hay or silage production (predominantly alfalfa).
Native Dominant Grasslands	Grasslands dominated by native grass species which may contain tame grasses and herbs.
Pasture	Grassland dominated by tame grass species.
Shrubs	Communities containing both low and tall shrub (e.g., snowberry, saskatoon, buffaloberry and willow)
Trees	Hardwoods, deciduous, spruce, mixed woods.
Wetlands	Intermittent water bodies, areas that have semi-permanent or permanent wetland vegetation, including marshes.
Open Waterbodies	All open water: lakes, rivers, streams, ponds and dug-outs.
Otherlands	Farmsteads, towns, cities and other odd areas.
Mud/ sand / saline	Exposed areas with little or no vegetation.

was accomplished using Spatial Analysis (Version 2.0), customized for this specific purpose and completed post field season.

Also, I used the Predicted Waterfowl Breeding Distribution DSS for the Canadian Prairie Pothole Region (DUC and IWWR 1999b) as a basis to compare grassland bird community composition and gross level habitat characteristics among areas of differing predicted duck density. This GIS-based regional conservation map product is constructed by combining four main data layers: the USFWS/CWS (United States Fish and Wildlife Service and Canadian Wildlife Service) air-ground waterfowl surveys segment (28.8 km x 0.4 km), quarter section level wetland characteristics derived from DUC's Wetland Habitat Inventory, the Canadian Land Inventory Capability (CLI) for Waterfowl, and Ecoregions of Canada. All relevant data were aggregated to a common spatial scale of 28.8 km x 1.6 km (46 km^2).

Abundance of 5 dabbling duck species: mallard (*Anas platyrhynos*), blue-winged teal (*Anas discors*), northern pintail (*Anas acuta*), northern shoveler (*Anas clypeata*), and gadwall (*Anas strepera*) and 2 diving duck species: canvasback (*Aythya valisineria*) and redhead *(Aythya americana*) were modeled as a function of total number of wetlands, CLI, and open marsh area. Predicted density values derived from segment level information were assigned to each quarter section within the 46 km^2 window, and then interpolated over the entire region. Associated annual variation (i.e., coefficient of variation) in waterfowl counts in southern Saskatchewan based on duck surveys varies from 0.15 to 0.60 (IWWR unpubl. data). The result is a colour-coded map that displays the spatial distribution of ten classes of predicted waterfowl pair density (ranging from < 4 to > 38 duck pairs per square kilometer) across the prairie and parkland ecoregions of Alberta, Saskatchewan and Manitoba and is used to assist resource managers in making general decisions regarding waterfowl recruitment potential of a given area.

I aggregated 10 original duck breeding pair density classes into low (<8 pairs/ km^2), medium (>8 to <15 pairs/ km^2) and high (>15 pairs/ km^2) duck density strata within my study area (Figure 2.1). For practical planning purposes, 3 classes were chosen to allow for comparisons of bird and habitat data across contrasting predicted duck densities and also to ensure adequate area for about equal number of routes in each general duck density stratum.

2.2.2 Bird surveys

Intensive grassland bird identification training and distance estimation, with emphasis on aurally detected birds, occurred in mid-May 2001 at Last Mountain Lake, SK, with Brenda Dale (Non-game bird coordinator, Canadian Wildlife Service, Edmonton) prior to commencement of surveys. Observers also regularly listened to bird recordings and routinely compared identification skills.

Point count transects were conducted from the last week in May to second week in July 2001 and 2002, following a typical bird survey protocol (Bibby et al.2000). BBS-style transects were distributed according to a random stratified design in each of three levels of predicted waterfowl breeding densities. To reduce systematic biases, route allocation was assigned randomly, with each observer (S. Skinner and one assistant each year) conducting roughly the same number of routes in each stratum each week. Surveys began 0.5 hours before and ended 4 hours after sunrise (08:30 to 09:00) on days with light to moderate winds (< 30 km/hr) and little precipitation. Transects were 32 km long with 40 stops at 800 m intervals. Each observer recorded all birds seen and heard in a 400-m radius plot in 3 minutes. Six routes per duck density stratum were randomly selected and surveyed in each year to directly assess annual variation in bird abundances and species richness.

2.2.3 Grassland bird groups

Bird abundance data were reduced to a "core" group each year by excluding rare species (i.e., species that occurred < 20% of all unique survey routes each year), species poorly sampled using roadside survey techniques (e.g., gulls, grouse, owls) or colonial species (e.g., black tern, red-necked grebe; scientific name of birds are given in Appendix B, Table B.1). To compare grassland bird communities among the duck density strata, I classified all core species into 3 key grassland bird categories. First, I grouped all core duck species encountered; three large groups of ducks (i.e., n > 50) identified as field feeders or fly-overs were assumed to represent transient, non-breeding or questionable breeders and were excluded. Second, a sub-sample of grassland species identified by the Committee On the Status of Endangered Wildlife in Canada

(COSEWIC) or Partners in Flight (PIF) as species of concern within BCR 11 were classed as “priority” group (Table 2.2). Le Conte’s sparrow was included in 2001 analyses but not in 2002 when it was detected on < 20% of unique routes. Third, all core species other than those included in the duck and priority species groups were categorized as “common”.

2.2.4 Distance sampling

Distances to visually detected birds from observers were estimated (with aid of a Bushnell Yardage Pro 500 ® laser range finder, accurate ± 1 m out to 500 m) for all prairie breeding shorebirds and all passerines except blackbirds and corvids. Preliminary observations confirmed detection probabilities for excluded species were consistently high among all habitats out to 400 m. Distances estimated from aurally detected birds proved unreliable and only distance estimates based on visual detections were used in subsequent analyses (Appendix A).

For both data chapters, I assessed whether visual and behavioural characteristics affected species-specific detection probabilities. I selected 9 species with contrasting plumage colouration or pattern, large body size, or distinctive display behaviour as “conspicuous” whereas six species of cryptic colour or behaviour were classed as “inconspicuous” to explore the extent of detection differences between the 2 groups (Appendix B**,** Table B.1). I predicted that conspicuous species would be detected at greater distances than inconspicuous species. Detection correction factors were derived for both conspicuous and inconspicuous species and applied to priority species stop level counts (Table 2.2). Detailed methods, analyses, and results are presented in Appendix A.

2.2.5 Landscape composition and configuration

Area (hectares) of each land cover class based on the digital land cover map was calculated and totaled within each 400-m radius circle from the center of all stops surveyed in 2001 and 2002. I quantified percentages of habitat composition and spatial structure (i.e., configuration of habitat patches) of all land cover classes at 2 spatial scales: (1) in Chapter 2, habitat composition (%) and mean structure metrics were calculated at the route level and (2) in Chapter 3, stop level habitat composition and

Table 2.2. Status and expected occurrence of bird species that use grassland habitat with high conservation priority in BRC 11, present in all 3 strata and detected in > 20% of survey routes in southcentral Saskatchewan, 2001 and 2002.

	Priority			Expected within
Common name	PIF[a]	COSEWIC[b]	1° Endemic[c]	study area[d]
Baird's Sparrow*	x		x	x
Bobolink†	x			x
Chestnut-collared Longspur*	x		x	x
Grasshopper Sparrow*	x			x
Lark Bunting†	x		x	x
Le Conte's Sparrow[e]*	x			x
Marbled Godwit†			x	x
Nelson's Sharp-tailed Sparrow*	x			uncommon
Northern Harrier‡	x			x
Sprague's Pipit*	x	TH	x	x
Swainson's Hawk‡	x		x	x
Wilson's Phalarope†			x	x

[a] Priority species as identified by Partners In Flight (PIF) Landbird Conservation Plan for BRC 11 based on distribution, local stewardship responsibility rank, population trends, and species vulnerability.

[b] Species risk category as identified by the Committee On the Status of Endangered Wildlife in Canada (COSEWIC): TH =Threatened.

[c] Primary endemic grassland bird species as identified by Mengel (1970). These species have narrow environmental tolerances and are historically restricted to the prairie grassland ecoregion.

[d] Core range overlaps with study area (Smith 1996).

[e] Le Conte’s sparrow was not included in 2002 analyses (encountered < 20% of 2002 routes).

* Inconspicuous species: counts multiplied by detection correction factor of 2.75.
† Conspicuous species: counts multiplied by detection correction factor of 2.25.
‡ Original count data used.

patch structure within each 400-m radius were considered. I did not report patterns at finer scales (e.g., 200-m radius) because of strong correlation among habitat variables out to 400 m (Bakker et al. 2002, Browder et al. 2002, Fletcher and Koford 2002).

Digital land cover grid images were converted to vector polygons using Spatial Analysis (Version 2.0). Area (ha) of all land cover classes, total number of patches, mean patch size, total edge, and mean core area were calculated using Patch Analyst extension (Version 2.2) of ArcView 3.2 (Elkie et al. 1999; Table 2.3). Habitat patch was defined as a discrete area of contiguous land cover class, distinguished by a polygon boundary (i.e., edge) with a minimum resolution (i.e., patch grain) of 0.09 ha (McGarigal and Marks 1994). Number of habitat patches and mean patch size are typical, although opposing, measures of landscape fragmentation or heterogeneity; larger patch size reflects a more homogeneous landscape (Coppedge et al. 2001a). Mean core area is the area within a given habitat patch > 100 m from a polygon edge (Helzer and Jelinski 1999, Saab 1999, Coppedge et al. 2001a). Core area is considered free from "edge effects" and is associated with population viability of area sensitive species (McGarigal and Marks 1994, Andrén 1994, Gustafson 1998). Total patch edge reflects patch shape; greater edge indicates patches that have higher edge to interior ratio and a more convoluted shape (McGarigal and Marks 1994). Proportion of edge habitat may influence reproductive success or bird behaviour (i.e., attract or repel individuals; Helzer and Jelinski 1999, Graham and Blake 2001).

The Shannon-Weiner (H') diversity index was also calculated to describe diversity or heterogeneity of habitat patches within each stop point (Flather and Sauer 1996, Gustafson 1998, Poague et al. 2000, Coppedge et al. 2001a, Lichstein et al. 2002a):

$$H' = -\sum_{i=1}^{m} (p_i)(\log_2 p_i) \tag{2.1}$$

where m is the number of land cover classes and p_i equals the proportion of total patches that are type i. H' index reflects the likelihood that one patch type will be the same as the next (Zar 1999). Stops or routes with fewer, more contiguous habitat patches will have a low patchiness index whereas stops or routes with multiple habitat types within the delineated boundaries will have a high habitat diversity index. Finally, number of patches, mean patch size and mean core area of native grassland pasture were also

Table 2.3. Description of patch level attributes used as independent environmental variables in conjunction with land cover classes included in multivariate (Chapter 3) and ordination (Chapter 4) analyses to assess habitat use patterns by grassland birds in Southern Saskatchewan, 2001 and 2002 (McGarigal and Marks 1994).

Patch-level attributes	Description
All landcover classes	
Number of patches	Sum of habitat patches within each stop or route.
Mean patch size	Mean patch size (ha) in each stop or route (total area of stop or route/ number of habitat patches).
Total edge	Total perimeter (m) of all patches in each stop or route.
Mean core area	Mean core area (ha) in each stop or route (total area > 100 m from patch perimeter / number of habitat patches with core areas).
Heterogeneity index	Shannon-Wiener diversity index (H'). A relative measure of patch diversity. The index will equal zero when there is only one patch in the landscape and increases as the number of patch types or proportional distribution of patch types increases.
Native dominant grassland	
Number of native patches	Sum of native grassland patches within each stop or route.
Mean native patch size	Mean native patch size (ha) in each stop or route (total native grassland area of stop or route/ number of patches).
Mean native core area	Mean native core area (ha) of native grasslands in each stop or route (total area > 100 m from native patch perimeter / number of native habitat patches with core areas).

calculated because configuration and degree of fragmentation of grassland patches on the landscape are also thought to affect habitat use and productivity of endemic grassland species (McGarigal and Marks 1994, Helzer and Jelinski 1999, Coppedge et al. 2001a, Fletcher and Koford 2002).

CHAPTER 3. RELATIONSHIPS BETWEEN RELATIVE ABUNDANCE AND SPECIES RICHNESS OF DUCKS AND GRASSLAND BIRDS

3.1 Introduction

Many grassland birds of North America are declining at a greater rate than birds associated with other habitats, even though many share common wintering areas (Samson and Knopf 1994, Herkert 1995, Peterjohn and Sauer 1999, Downes et al. 2003). Canadian Breeding Bird Survey (BBS) trend data indicate grassland bird populations in Bird Conservation Region (BCR) 11 (Prairie Pothole region in Alberta, Saskatchewan and Manitoba and north central US) have declined at an average rate of 1.5% per year (1969- 2002). These long-term population declines have been attributed to loss and degradation of natural grassland habitats (Samson and Knoph 1994, Houston and Schmutz 1999, Vickery et al. 1999, Smith and Radenbaugh 2000).

North American bird conservation programs have typically been aimed at individual taxonomic groups such as shorebirds, land birds or waterbirds, each with separate goals and objectives. For example, conservation initiatives in the Canadian prairie region have focused primarily on increasing waterfowl populations to average levels recorded in the 1970s through the North American Waterfowl Management Plan (NAWMP) established in 1986 (Anderson et al. 1995, Williams et al. 1999). More recently, broad, community level planning for all avian species has gained momentum.

The North American Bird Conservation Initiative (NABCI) was launched in 1998 to, “achieve regionally based, biologically driven, landscape oriented partnerships”, by building on existing structures such as national and international bird conservation initiatives and regional joint ventures in Canada, the US and Mexico (Downes et al. 2000, Martell et al. 2002). Presently, the Prairie Habitat Joint Venture (PHJV) provides a forum for the integration of waterfowl, waterbird, shorebird, and land bird conservation working groups. These integrated approaches have fostered greater awareness for grassland bird conservation, specifically for those species listed as species of conservation concern by the COSEWIC and PIF. Here, I address this issue of multi-species avian conservation by discussing how waterfowl conservation activities may contribute to broader bird conservation.

In general, duck home ranges (8-280 ha; Nudds and Ankney 1982) vastly exceed area needs of most grassland songbirds (territory size ~1.5 ha; Dechant et al. 2003a and Dinkins et al. 2003) and typically include a broad array of wetland types (e.g., shallow marshes to deep, open waterbodies) and upland cover (i.e., native cover, forage, shrubs) for foraging, pairing, nesting habitat, and brood rearing habitats (Greenwood et al. 1995, Williams et al. 1999, Mack 2003). Wetlands are not only critical habitat for waterfowl, but are also important staging areas for migrating shorebirds. Moreover, vegetated zones surrounding wetlands are important nesting habitat for some species including northern harrier (*Circus cyaneus*; Dechant et al. 2003d), sedge wren (*Cistothorus platenis*; Dechant et al. 2003h), Wilson's phalarope (*Phalaropus tricolor*; Jackson 2003) and Nelson's sharp-tailed sparrow (*Ammodramus nelsoni*; Dechant et al. 2003f). Perennial cover (i.e., native and tame pastures, forage, shrubs) provides nesting and foraging habitat for a variety of landbirds (Renken and Dismore 1987, Hartley 1994, Dale et al. 1997, Davis and Duncan 1999, Davis et al. 1999, McMaster and Davis 2001), shorebirds (Ryan et al.1984, Jackson 2003) and ducks (Johnson and Schwartz 1993, Greenwood et al. 1995, Reynolds et al. 2001, Mack et al. 2003). Thus intensive (i.e., habitat securement and enhancement) or extension (e.g., grazing systems or forage conversion) programs primarily aimed at waterfowl have the potential to yield significant benefits to other birds as well as enhance biodiversity on the Canadian prairies (Dale 1994, Hartley 1994, Anderson et al. 1995, Johnson 1996, Prescott and Murphy 1999) in a practical and economically efficient manner (Simberloff 1998, Suter et al. 2002, Lawler et al. 2003).

Recovery of northern pintails (*Anas acuta*) in the prairie region is currently a primary goal of duck conservation agencies and habitat conservation effort is being focused in key pintail areas (e.g., Missouri Coteau) because continental populations have failed to reach levels set by NAWMP (Miller and Duncan 1999, Prodruzny et al. 2002). Given that the pintail's open grassland habitat requirements may overlap with those of other grassland bird species, the pintail may be a reliable "indicator" for other grassland endemics (Landres et al. 1988, Simberloff 1998, Chase et al. 2000). However, some grassland species require large, contiguous tracts of native prairie where pintails may not be common. Thus, in this situation, abundance of pintails could be a poor indicator of other grassland birds.

Currently, the Predicted Waterfowl Breeding Distribution DSS, based on long-term waterfowl and wetland data is used to target management to areas of greatest waterfowl potential. However, similar large-scale predictive models are lacking for most grassland birds species other than ducks (Madden et al. 2000, Niemuth 2003, Davis 2003). As many of these species are currently declining throughout the prairie pothole region, it is essential to determine the extent to which conservation activities in areas of high priority for ducks contribute to conservation goals for other grassland species, especially those of special conservation concern.

Therefore, my main objective was to describe grassland bird community composition and abundance in relation to landscape level habitat characteristics among areas of differing predicted duck densities. Because the duck community has diverse habitat requirements that often involve relatively large areas, I hypothesized that ducks may function as indicator or umbrella taxa of overall upland breeding habitat quality for other grassland bird species (Landres et al. 1988, Chase et al. 2000, Poiani et al. 2001, Suter et al. 2002). Waterfowl and other grassland bird species that share common habitats may be affected in similar ways by processes such as habitat loss or fragmentation, producing covariation in patterns of bird abundance and species richness (Johnson 1996). Thus, I predicted in areas of greater duck potential would include a greater variety of habitat types that would support a higher diversity of other grassland species than in areas of low duck potential. I determined the strength of correlation between ducks and other grassland birds and how species richness and abundance of 3 grassland bird groups differed among various duck density strata.

3.2 Methods

Point count surveys were conducted from late May to early July 2001 and 2002, using a modified BBS protocol. Detailed descriptions of the study area and field methods are provided in Chapter 2.

3.2.1 Statistical analysis

Bird abundance data were reduced to a "core" group each year and were classified into 3 key grassland bird categories: ducks, priority and common (i.e., core non-priority and non-duck species; see Chapter 2 for details). All subsequent analyses except those assessing annual variation were conducted with a subset of stops and routes "unique" to each year. Half the routes surveyed in both years were randomly assigned either to 2001 or 2002 to ensure complete independence between years.

3.2.1.1 Associations between duck and other grassland bird species

Associations between total abundance and total species richness of other grassland bird species (i.e., priority and common "core" species) and 7 duck species (used to create DUC's DSS) were assessed using Pearson's product- moment correlation coefficients and linear regression each year. To improve normality and homogeneity of variance, duck count data were square root transformed (Zar 1999). I also investigated whether total pintail abundance was correlated with total priority species abundance and richness. Lastly, I conducted correlation analyses within each duck density stratum to determine whether associations between duck and other grassland bird species were consistent among strata.

3.2.1.2 Species richness

Stratum-level species richness for all core ducks, priority, and common species encountered along stops unique to 2001 and 2002 were estimated by rarefaction procedures using the computer program, Species Estimator (Colwell 1997). Rarefaction is a statistical method that estimates expected species richness based on multiple random sampling from the complete data set (James and Rathbun 1981). Count data from each duck density stratum in each year were re-sampled 100 times (without replacement) and expected richness was plotted. This technique was also used to determine minimum sample effort (i.e., number of stops) required to estimate species richness to within 5% of maximum species detected per stratum for each key bird group.

3.2.1.3 Species abundance

I used General Linear Models (GLM) to test whether total abundance (stop level) of each bird group differed among duck density strata and year and whether patterns of variation among strata were consistent between years. To compare local and landscape level differences in bird group abundance patterns among and within duck density strata in 2001 and 2002, a series of nested analyses of variance (hereafter nested ANOVA) using all point count stops along unique routes (routes nested within stratum) was performed to determine within and among stratum variance in total abundance. Counts of zero ducks and priority species were frequent; square root transformation and multinomial classification did not improve normality, so raw count data were used. All priority species were classed as conspicuous or inconspicuous and raw counts were corrected using appropriate detection correction factors (i.e., 2.25 for conspicuous species and 2.75 for inconspicuous species; Swainson's hawk and northern harrier counts were not modified; Table 2.2; Appendix A). The Bonferroni pair-wise comparison was used for "a posteriori" contrasts of stratum level marginal means when nested ANOVA indicated significant stratum-level effects. The Bonferroni method adjusts the observed significance level to account for multiple comparisons (Rice 1989). All analyses were performed with SPSS version 11.0.1 (SPSS 2001).

3.2.1.4 Landscape composition and configuration

I quantified spatial composition and configuration (i.e., landscape structure) of 10 land cover classes within a 400-m radius from the center of each stop point within each unique route surveyed in 2001 and 2002 using Patch Analyst extension (Version 2.2) of ArcView 3.2 (Elkie et al. 1999). See Chapter 2 for detailed description. Full-factorial multivariate analysis of variance (MANOVA) was conducted with 2001 and 2002 route level habitat variables to determine if habitat composition (%) and landscape structure differed among duck density strata.

3.2.1.5 Annual variation

Using a sub-sample of 626 stops along 17 routes surveyed in both years, I conducted nested ANOVAs to test for variation in annual differences of total area of each land cover class (ha) per stop (within a 400-m radius), and mean abundance and species richness each bird group among and within strata. Raw counts of all priority species were corrected using appropriate detection correction factors (i.e., 2.25 for conspicuous species and 2.75 for inconspicuous species; Appendix A). I also made pair-wise comparisons of annual stratum-specific differences in route-level mean abundance and species richness (Zar 1999). Mean differences between years were compared based on 95% confidence intervals (CIs); CIs that included zero were consistent with a null hypothesis of no annual variation. Stratum-specific route level relative abundances for all individual core species (i.e., ducks, priority and common species) were calculated to directly compare annual variation in species abundance (Appendix B, Table B.3). To gain additional information on annual variation in duck abundance and wetland conditions, I compared total indicated ducks and total number of full ponds in 2001 versus 2002 along 2 waterfowl breeding population and habitat survey air ground comparison segments within the study area (i.e., Ceylon and Goodwater segments; USFWS and CWS 2001 and 2002).

3.3 Results

3.3.1 Bird surveys

One hundred and twenty-three grassland bird species were encountered at 3,534 stop points on 93 routes in 3 waterfowl density strata during 2001 and 2002 (Table 3.1; Appendix B, Table B.2). Seventeen routes were surveyed in both years (626 stops). A total of 119 species was recorded on 74 "unique" routes (2,797 stops); black-billed cuckoo (*Coccyzus erythropthalmus*), ferruginous hawk (*Buteo regalis*), and stilted sandpiper (*Calidris himantopus*) were not encountered along this subset of routes. Overall, 61 core (i.e., encountered > 20% unique routes) species were recorded in 2001 compared to 57 species commonly detected in 2002. Several "incidental" species (i.e., encountered < 20% unique routes) were only encountered in 1 of 2 years. In total, 63 core species recorded on unique routes during both years were included in subsequent species richness and abundance analyses (Appendix B, Table B.4).

3.3.2 Associations between duck and other grassland bird species

In general, moderate, positive correlations were found between total duck and total grassland bird (i.e., common and priority groups) species abundance and richness across all duck density strata in both 2001 and 2002 (species richness: 2001: $r = 0.57$, $n = 41$; 2002: $r = 0.69$, $n = 33$, all $Ps < 0.001$; abundance: 2001: $r = 0.41$, $n = 41$; 2002: $r = 0.37$, $n = 33$, all $Ps < 0.05$; Figures 3.1a and 3.1b). In all cases, explained variation among these associations was moderate to low ($0.48 > r^2s < 0.14$, all $Ps < 0.03$). Only total priority species richness was moderately correlated with total pintail abundance in both years (2001: $r = 0.34$, $n = 40$, $P = 0.033$; 2002: $r = 0.42$, $n = 33$, $P = 0.016$; Figures 3.2a and 3.2b); however, there was no relationship between pintails and priority grassland species total abundance in both years (2001: $r = 0.14$, $n = 40$, $P = 0.34$; 2002: $r = 0.039$, $n = 33$, $P = 0.83$).

Table 3.1. General description of sampling effort for birds in low (< 8 duck pairs/ km^2), medium (> 8 to < 15 pairs/ km^2) and high (>15 pairs/ km^2) predicted waterfowl breeding distribution strata, in the Missouri Coteau region of southern Saskatchewan, late May - early July 2001 and 2002.

	2001				2002				
Variables	Low	Medium	High	SubTotal	Low	Medium	High	SubTotal	*Total*
Number of routes surveyed	15	18	19	52	14	13	14	41	*93*
Number of new routes surveyed					8	8	8	24	*24*
Number of routes re-surveyed					6	5	6	17	*17*
Number of stop points	560	698	675	1,933	542	514	545	1,601	*3,534*
Total birds recorded	5,969	11,796	12,644	30,409	6,540	8,306	12,083	26,929	*57,338*
Total species	88	76	90	107	76	91	89	106	*123*

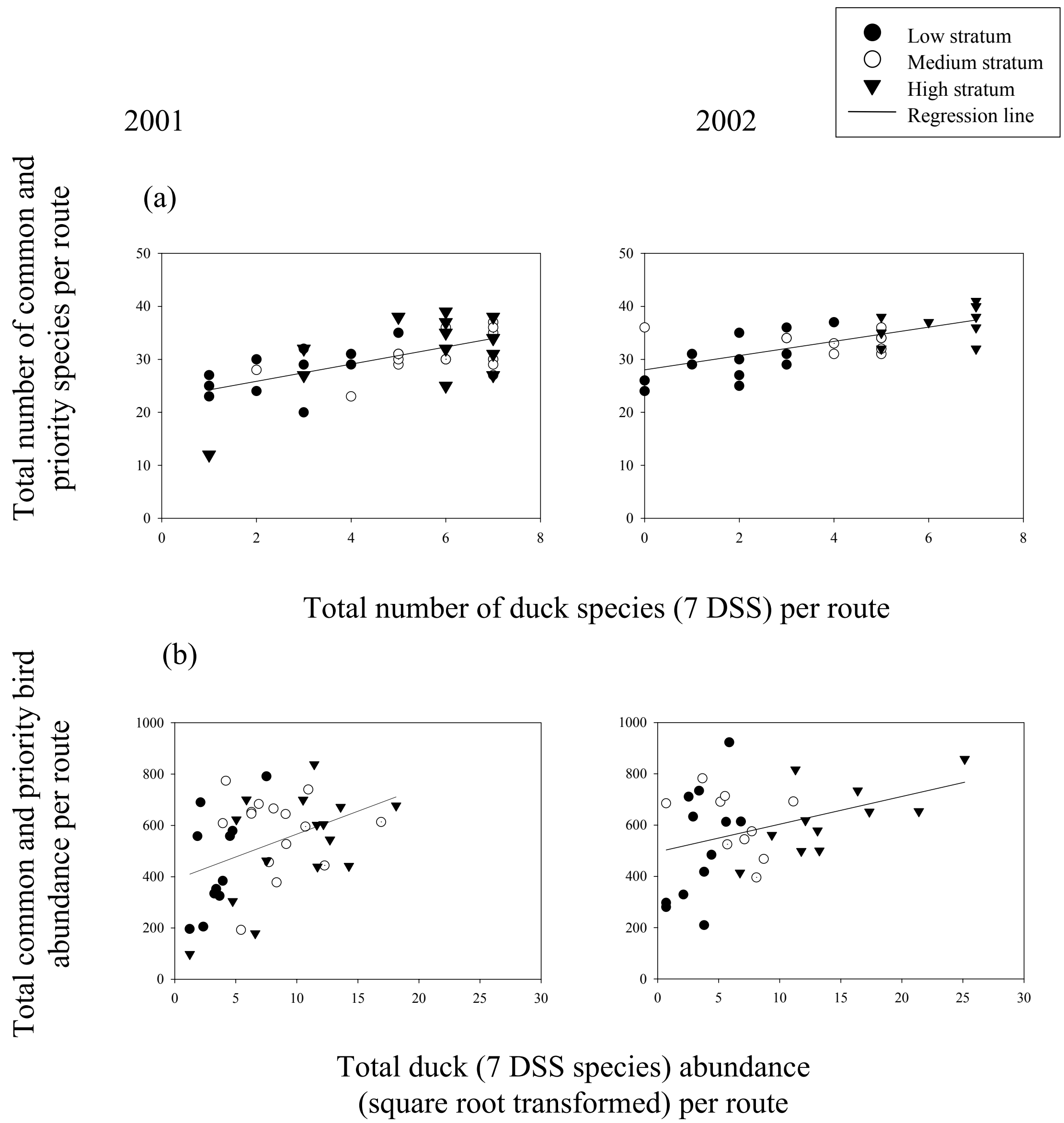
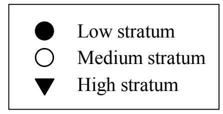
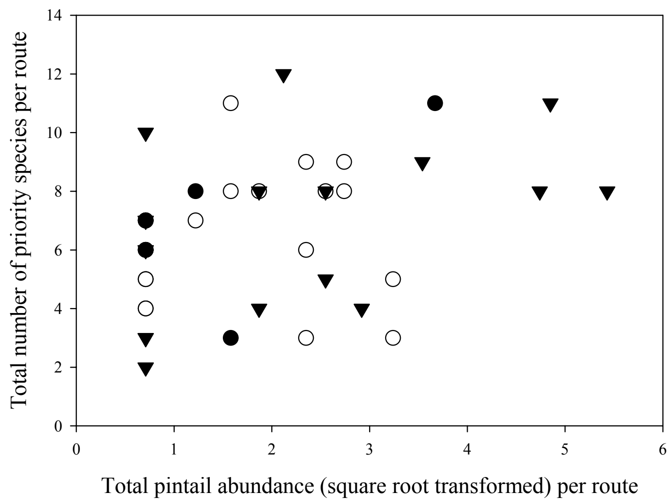


Figure 3.1. Route level relationships between 7 duck species used to create DUC DSS and all other grassland bird species in 2001 (left side; n = 49 species) and 2002 (right side; n = 45 species) for: (a), total number of common and priority species per route as a function of total duck species per route; and (b), total abundance of common and priority species per route as a function of total duck abundance per route. Line of best fit determined by linear regression.



(a) 2001



(b) 2002

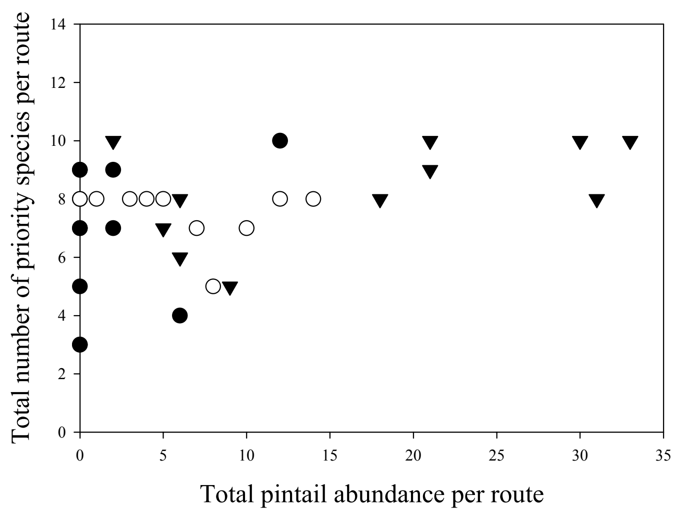


Figure 3.2. Route level relationship between total pintail abundance per route and priority species abundance per route in: (a) 2001 and (b) 2002. Note that x-axis scale changes between years.

Overall, ducks and other grassland bird species tended to be positively associated in low and high duck density strata but there was little association in medium stratum. Moderately positive correlations between duck and other grassland bird species richness were found in low stratum in both years (2001: $r = 0.70$, $n = 11$, $P = 0.017$; 2002: $r = 0.69$, $n = 12$, $P = 0.013$) and in high stratum in 2001 ($r = 0.52$, $n = 15$, $P = 0.047$). Similarly, abundances of duck and other grassland bird species were moderately correlated in high stratum in both years (2001: $r = 0.556$, $n = 15$, $P = 0.031$; 2002: $r = 0.669$, $n = 11$, $P = 0.024$). In 2001, only total priority species richness and abundance were positively correlated with pintail abundance in low stratum (species richness: $r = 0.61$, $n = 12$, $P = 0.045$; abundance: $r = 0.73$, $n = 11$, $P = 0.011$).

3.3.3 Species richness and abundance of 3 grassland bird groups

3.3.3.1 Duck species

Duck data obtained from independent surveys corroborate the validity of DUC's DSS. In both years, estimated core duck species richness was greater in medium and high duck density strata than in low (Figure 3.3a). Canvasbacks, redheads and ruddy ducks were not recorded in low stratum in 2001; American wigeon, lesser scaup redheads and ruddy ducks were not encountered in low stratum and redheads were absent in medium stratum in 2002. Maximum estimated species richness (i.e., 10 species) in high stratum was attained in < 15 survey stops both years and < 60 stops were required to reach within 5% of maximum in medium strata in 2001. As other species (e.g., canvasback, blue-winged teal) were infrequently detected, far greater sampling effort was required in low and medium duck density strata to estimate 95% of maximum species richness in 2002. In all cases, number of stops needed to adequately estimate duck species richness was exceeded.

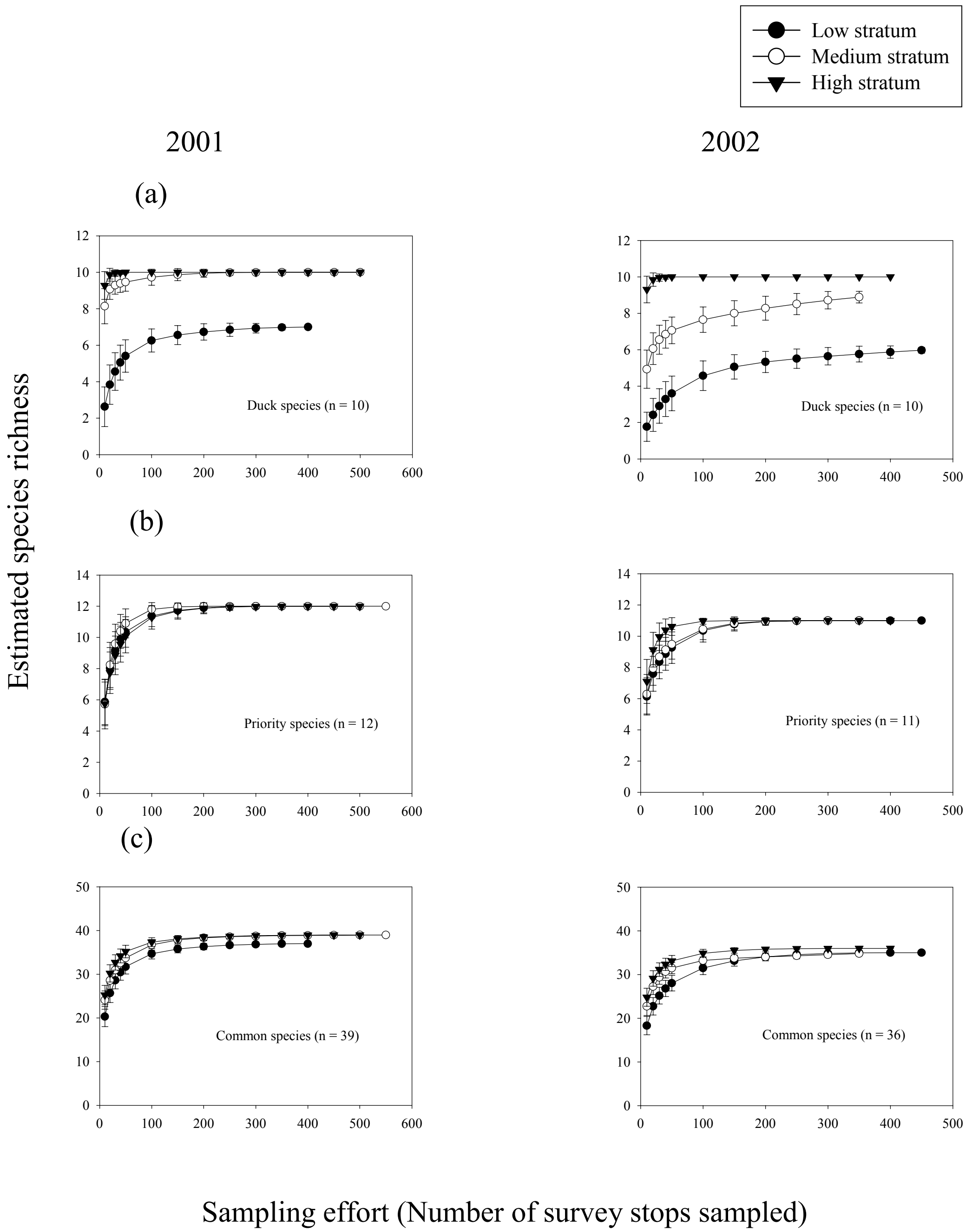


Figure 3.3. Rarefaction curves for 2001 (left side) and 2002 (right side) showing estimated sample species richness (± SD) detected with increasing numbers of survey stop points along "unique" routes in low, medium, and high waterfowl density strata for: (a) duck species; (b) priority species; and (c) common species. Note that y-axis scale changes among bird groups.

Patterns of mean duck abundance among duck density strata were not consistent between years, so I conducted nested ANOVAs by year. In both years, total duck abundance varied among and within duck density strata (nested ANOVAs, all Ps < 0.001). In 2001, more ducks were encountered in high duck density stratum than in medium, and greater number of ducks in medium than low (Bonferroni comparisons, Ps < 0.004). However, individual mean abundances of canvasbacks, northern pintail and lesser scaup did not vary among strata. In contrast, 2002 total duck abundance was greatest in high stratum but low and medium duck density strata were similar (Bonferroni comparisons, P = 0.56; Appendix B, Table B.4). Duck community composition was similar between years along unique routes; mallard and blue-winged teal were most abundant and most frequently detected but few bufflehead and green-winged teal were encountered on < 20% of unique routes in both years. Although total duck abundance was similar between years (marginal means ± SE, 2001: 2.35 ± 0.23; 2002: 2.54 ± 0.25, P = 0.57), mean duck abundance in high stratum was greater in 2002 compared to 2001 (Appendix B, Table B.4).

3.3.3.2 Priority species

Sampled areas of differing duck density supported about equal numbers of priority species in 2001 and 2002; a minimum of 115 stops was required for reliable estimates of species richness (95% of maximum) in all duck density strata both years (Figure 3.3b). Le Conte’s sparrow was not included in 2002 rarefaction analysis because only 6 individuals were encountered at 5 stops along 4 routes.

Patterns of priority species abundance (corrected for detection differences) among strata were similar in both years; slightly more priority birds were encountered in low duck density stratum than in medium (nested ANOVA: $F_{2,71} = 3.50$, P = 0.03; Bonferroni comparisons, P = 0.025) and differences in total abundance were found among routes within strata (nested ANOVA: $F_{71, 2723} = 5.16$, P < 0.001). Only bobolink mean abundance was higher in low than medium or high strata and Wilson’s phalaropes were more common in high compared to low stratum (All 1-way ANOVAs, Ps < 0.05). However, more birds were encountered along 2002 stops compared to 2001 (marginal means ± SE, 2001: 2.52 ± 0.16; 2002: 3.60 ± 0.18, P < 0.001). Notably, in 2002 mean abundance of lark buntings was greater in low and high duck density strata than in 2001 (Appendix B, Table B.4).

3.3.3.3 Common species

Estimated species richness was greatest in high density stratum regardless of year but more species were recorded in 2001 (Figure 3.3c). Horned and pied-billed grebes were not detected in low stratum in 2001 while in 2002, American avocets were not encountered in low stratum and sedge wrens were not recorded in medium stratum. Greater sampling effort was required in low duck density stratum than in medium or high in both years but < 200 stops were required to reach 5% of maximum species in all 3 strata each year.

In both years, relative abundance of common species was greatest in the high density waterfowl stratum when compared with the low (nested ANOVA, 2001: $F_{2,38} = 50.9$, $P < 0.001$; 2002: $F_{2,30} = 48.8$, $P < 0.001$) and within-stratum variation was evident (nested ANOVAs, all Ps < 0.001). However, species abundances in medium and high strata were very similar in 2001 (Bonferroni pair-wise comparisons, $P = 1.00$). In contrast, differences were detected among all 3 strata in 2002 (Bonferroni pair-wise comparisons, $P < 0.018$).

Overall abundance was similar between years (marginal means ± SE, 2001: 12.2 ± 0.19; 2002: 11.9 ± 0.20, $P = 0.23$) and horned larks, red-winged black birds and brown-headed cowbirds were most common both years. Individual mean abundances of some wetland-associated species (i.e., American coot, common snipe, sora rail, and red-winged and yellow-headed black birds) were all greater in high stratum; brown-headed cowbirds were most common in high and medium strata compared to low in both years. However, high duck stratum supported more wetland-associated species than low stratum in 2002 versus 2001. In addition, mean abundance of western meadowlark was significantly higher in 2001 whereas brown-headed cowbirds were most abundant in 2002. (Appendix B, Table B.4).

3.3.4 Habitat composition and configuration

Forty percent of all unique stop points surveyed in each year were digitally corrected (n = 1107); most common corrections resulted from conversion of crop to forage or tame pasture and omission of wetlands. Among subset of re-sampled routes, additional habitat changes were made at 202 (31%) stop points in 2002 due to forage and crop rotations and many flooded wetlands in 2001 became dry and were tilled or hayed in 2002. In total, 47% (n = 1309) of stops were corrected at least once in both years.

Duck density strata differed with respect to the 10 habitat variables (MANOVA: Wilk's Lambda = 0.110, df = 34, P < 0.001; Table 3.2). Specifically, the landscape within high duck density stratum was more heterogeneous and contained a greater number of smaller, irregular shaped habitat patches (i.e., greater total edge and lower mean core area), greater areas of forage, shrub, wetlands, and open water bodies compared to low and medium strata (Bonferroni comparisons, all Ps < 0.016). In contrast, low stratum contained larger, more uniformly shaped habitat patches and greater proportion of cropland compared to medium and high (Bonferroni multiple comparisons, all Ps < 0.015).

3.3.5 Annual variation

3.3.5.1 Species richness and abundance

Annual variation in duck species richness and abundance among strata was evident (nested ANOVAs: species richness: $F_{2, 14} = 12.51$, P < 0.001; abundance: $F_{2, 14} = 8.93$, P < 0.001). Duck species richness also varied among routes within strata (nested ANOVA: $F_{14, 609} = 3.17$, P < 0.001). More duck species were encountered in 2001 than in 2002 in medium duck density stratum (paired t-test: t = 3.01, d.f. = 189, P = 0.003) whereas species richness was greater in 2002 in high stratum (paired t-test: t = -3.13, d.f. = 217, P = 0.002). Mean duck abundance was greater in 2002 than in 2001 in high duck density stratum only (paired t-test: t = -3.33, d.f. = 217, P = 0.001; Appendix B, Table B.3). Specifically, gadwall and northern pintail mean abundances in high stratum were greater in 2002 (Table 3.3). Duck species richness or abundance did not differ annually in low stratum (paired t-tests, Ps > 0.13). Mallard, blue-winged teal and gadwall were

Table 3.2. Route level summary statistics (mean ± 1 SE) for independent landscape attributes measured within each unique route distributed among 3 duck density strata in southern Saskatchewan (2001 and 2002).

	Duck density strata		
	Low (n = 23 routes)	Medium (n = 25 routes)	High (n = 26 routes)
Land cover classes			
Cropland (%)	74.7 ± 4.4	73.8 ± 2.9	59.9 ± 3.0
Forage (%)	2.5 ± 0.6	4.65 ± 0.7	7.0 ± 0.8
Native dominant grasslands (%)	17.0 ± 3.7	11.9 ± 2.2	18.2 ± 2.5
Pasture (%)	2.0 ± 0.4	2.6 ± 0.4	2.7 ± 0.4
Shrubs (%)	0.8 ± 0.2	0.8 ± 0.1	2.2 ± 0.3
Trees (%)	0.2 ± 0.1	0.1 ± 0.0	0.2 ± 0.0
Wetland (%)	1.2 ± 0.2	3.4 ± 0.2	6.2 ± 0.4
Open waterbody (%)	0.3 ± 0.1	0.7± 0.2	1.7 ± 0.3
Other lands (%)	1.1 ± 0.2	1.5 ± 0.2	1.2 ± 0.1
Mud/ sand/ saline (%)	0.2 ± 0.1	0.5 ± 0.2	0.7 ± 0.1

Continued.

Table 3.2. Continued.

	Duck density strata		
	Low (n = 23 routes)	Medium (n = 25 routes)	High (n = 26 routes)
Landscape structure			
Heterogeneity index	0.7± 0.1	0.9 ± 0.1	1.2 ± 0.1
Number of habitat patches	212.9 ± 26.6	361.3 ± 38.4	719.8± 86.8
Mean patch size (ha)	12.2 ± 1.7	6.5 ± 0.6	3.3 ± 0.3
Total edge (m)	199013.0 ± 12338.2	261432.1 ± 11285.2	375685.3 ± 27478.4
Mean core area (ha)	13.6 ± 1.0	9.2 ± 0.5	4.9 ± 0.3
Number of native patches	44.4 ± 7.2	50.3 ± 10.7	93.0 ± 12.8
Mean native patch size (ha)	7.0 ± 1.4	6.1 ± 1.0	4.0 ± 0.4
Mean native core area (ha)	5.3 ± 0.9	3.9 ± 0.9	1.6 ± 0.3

the most abundant ducks observed both years. Although total duck numbers were greater in 2002, most species were encountered at fewer stops along fewer routes, indicating ducks were less widely distributed across my study area relative to 2001. Indicated duck numbers in 2002 were 32% and 78% lower in 2001 along Ceylon and Goodwater waterfowl breeding population survey segments, respectively (USFWS and CWS 2001, 2002), possibly because of poorer wetland conditions (see details below).

Differences in priority species richness and relative mean abundance (corrected for detection differences) among strata were not detected between years (nested ANOVAs, all Ps > 0.2) although within-stratum variation was evident (nested ANOVAs: species richness: $F_{14, 609} = 3.06$, $P < 0.001$; abundance: $F_{14, 609} = 2.90$, $P < 0.001$). Both variables were consistently greater in 2002 than in 2001 in all 3 duck density strata (paired t-tests, Ps < 0.013), although individual mean abundances were similar among strata and between years (Appendix B, Table B.3). Only Wilson's phalarope was more abundant in high stratum compared to medium or low in 2002. Baird's sparrows and chestnut-collared longspurs were the most abundant priority species whereas northern harriers, Swainson's hawk, Nelson's sharp-tailed sparrow and Le Conte's sparrow were least common in both years (Table 3.3). Percentages of routes and stops where priority species were detected increased from 2001, indicating that these species distributions expanded locally.

Finally, between-year differences in species richness and abundance of common species did not vary among strata (nested ANOVAs, all Ps > 0.25) but annual differences in species richness varied among routes within strata (nested ANOVAs: species richness: $F_{14, 609} = 6.32$, $P < 0.001$; abundance: $F_{14, 609} = 8.04$, $P < 0.001$). While species richness among strata was similar between years (paired t-tests, all Ps > 0.166), more birds were detected in 2002 in all 3 strata (paired t-tests, Ps < 0.001).

Table 3.3. Mean (± 1 SE) abundance of core duck, priority and common species encountered along 17 routes sampled in 2001 and 2002 with stratum- or year-specific differences. The percentages of stops and routes where each species were detected are also given.

	2001						2002					
				Relative abundance						Relative abundance		
				Stratum						Stratum		
Common Name	Total detections	% Routes detected	% Stops detected	Low	Medium	High	Total detections	% Routes detected	% Stops detected	Low	Medium	High
Duck species												
Blue-winged Teal	196	76.5	8.6	0.08 ± 0.07	0.29 ± 0.17	0.54 ± 0.24	276	58.8	10.4	0.03 ± 0.03	0.17 ± 0.12	1.03 ± 0.41
Gadwall	159	70.6	8.0	0.03 ± 0.02	0.48 ± 0.20	0.30 ± 0.10	189	64.7	8.2	0.02 ± 0.01	0.14 ± 0.12	0.73 ± 0.14
Mallard	279	100	13.4	0.13 ± 0.04	0.58 ± 0.10	0.61 ± 0.18	454	94.1	15.8	0.12 ± 0.04	0.60 ± 0.34	1.40 ± 0.35
Northern Pintail	63	64.7	4.0	0.09 ± 0.06	0.12 ± 0.04	0.09 ± 0.05	111	64.7	6.2	0.01 ± 0.01	0.03 ± 0.02	0.44 ± 0.12
Priority species												
Baird's Sparrow	454	88.2	17.8	0.66 ± 0.20	0.75 ± 0.26	0.80 ± 0.23	638	88.2	25.0	0.95 ± 0.30	0.92 ± 0.31	1.18 ± 0.31
Chestnut-collared Longspur	308	64.7	10.6	0.75 ± 0.33	0.37 ± 0.17	0.31 ± 0.17	534	70.6	12.5	0.99 ± 0.39	1.03 ± 0.53	0.56 ± 0.27
Le Conte's Sparrow	30	35.3	1.4	0.02 ± 0.02	0.04 ± 0.03	0.08 ± 0.04	14	29	0.8	0.03 ± 0.02	0.00 ± 0.00	0.02 ± 0.01
Nelson's Sharp-tailed Sparrow	19	23.5	1.1	0.02 ± 0.02	0.07 ± 0.07	0.02 ± 0.01	52	58.8	2.6	0.03 ± 0.03	0.08 ± 0.03	0.14 ± 0.05
Northern Harrier	11	35.3	1.8	0.02 ± 0.01	0.02 ± 0.02	0.01 ± 0.01	12	47.1	1.8	0.03 ± 0.01	0.02 ± 0.01	0.01 ± 0.01
Swainson's Hawk	19	70.6	2.9	0.02 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	36	64.7	4.6	0.05 ± 0.03	0.06 ± 0.03	0.06 ± 0.02

Continued.

Table 3.3. Continued.

	2001						2002					
				Relative abundance						Relative abundance		
				Stratum						Stratum		
Common Name	Total detections	% Routes detected	% Stops detected	Low	Medium	High	Total detections	% Routes detected	% Stops detected	Low	Medium	High
Common species												
Brown-headed Cowbird	408	100	32.6	0.43 ± 0.18	0.85 ± 0.10	0.66 ± 0.25	1,018	100	52.8	1.24±0.25	1.91±0.41	1.63 ± 0.17
Canada Goose	117	64.7	6.4	0.11 ± 0.09	0.29 ± 0.12	0.15 ± 0.08	9	17.6	0.6	0.00 ± 0.00	0.01 ± 0.01	0.04 ± 0.03
Common Grackle	112	76.5	7.2	0.14 ± 0.04	0.22 ± 0.13	0.17 ± 0.10	297	100	16.8	0.35 ± 0.15	0.41 ± 0.06	0.65 ± 0.18
Eastern Kingbird	160	100	18.6	0.14 ± 0.03	0.37 ± 0.05	0.27 ± 0.05	236	100	22.6	0.25 ± 0.06	0.40 ± 0.10	0.47 ± 0.06
Horned Grebe	32	17.6	1.4	0.00 ± 0.00	0.01 ± 0.01	0.13 ± 0.12	0	0	0	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Horned Lark	1,165	100	77.3	1.91 ± 0.23	2.07 ± 0.31	1.59 ± 0.24	1,752	100	77.3	3.34 ± 0.23	2.66 ± 0.47	2.39 ± 0.22
Red-winged Blackbird	930	100	53.4	0.87 ± 0.31	1.58 ± 0.28	1.92 ± 0.24	1,065	100	48.2	1.33 ± 0.27	1.63 ± 0.40	2.02 ± 0.20
Savannah Sparrow	543	100	50.6	1.09 ± 0.24	0.80 ± 0.14	0.63 ± 0.07	666	100	56.3	1.59 ± 0.26	0.84 ± 0.17	0.77 ± 0.06
Western Kingbird	75	94.1	6.2	0.08 ± 0.02	0.16 ± 0.07	0.13 ± 0.02	143	100	11.7	0.17 ± 0.11	0.27 ± 0.09	0.27 ± 0.06
Western Meadowlark	532	100	63.5	0.79 ± 0.08	1.07 ± 0.19	0.70 ± 0.13	441	100	53.0	0.67 ± 0.12	0.80 ± 0.08	0.66 ± 0.09

Horned larks, red-winged blackbirds, savannah sparrows, and western meadowlarks were commonly encountered species in both years (Table 3.3). Brown-headed cowbirds, common grackles, and eastern and western kingbirds were more abundant in 2002 than in 2001 whereas fewer Canada geese and sora rails were detected in 2002. Brown-headed cowbirds were more prevalent in 2002 than 2001 in all 3 strata (Appendix B, Table B.3). In 2002, horned grebes were not encountered along any re-sampled routes. Overall distribution of common species appeared constant between years (i.e., detected on similar % of routes in both years).

3.3.5.2 Habitat

Land cover composition demonstrated little annual variation among all 3 duck density strata (nested ANOVAs, all Ps > 0.15). Only shrub area was greater in medium and high strata in 2002 compared to 2001 (nested ANOVA, $F_{2, 14} = 5.52$, $P = 0.004$; paired t-tests: medium stratum: $t = 3.07$, d.f. = 189, $P = 0.002$; high stratum: $t = 2.18$, d.f. = 217, $P = 0.03$). Improved delineation and classification of shrub habitat during 2002 land cover updates, rather than actual increase in shrub coverage, likely accounted for this result.

Although measured wetland area did not decline in 2002 from 2001, southern Saskatchewan experienced drought conditions in 2001 and 2002 resulting in extremely low 2002 soil moisture and water levels (Agriculture and Agri-Food Canada 2003, Environment Canada 2003). Precipitation data from 6 weather stations within the study area corroborate this trend; 2001-2002 fall and winter precipitation was ~ half the levels recorded during 2000-2001, being about 35-73 % of long-term mean during 1971-2002 (Environment Canada 2003). Accordingly, 32% and 79% fewer full semi-permanent and permanent ponds were recorded along the Ceylon and Goodwater waterfowl survey transects (respectively) in 2002 when compared with 2001, suggesting that more wetland basins were dry in 2002.

3.4 Discussion

Using ducks as indicator or umbrella taxa of abundance and species richness of other grassland bird species was moderately successful, suggesting that this approach may facilitate initial selection of areas of high conservation value for multiple grassland bird species but will not directly benefit the development of conservation plans for priority species (Kerr 1997, Poiani et al. 2001). This conclusion stems from 2 main lines of evidence. First, moderate covariation in patterns of measured duck and other grassland species (i.e., priority and common species) richness and abundance was found but over 50% of the variation between grassland bird and duck species was not explained (Figure 3.1a and 3.1b) at this spatial scale (i.e. route level). One explanation for large residual errors of the regressions between duck and other grassland species is that habitat effects other than wetland area (which is a good predictor of duck density) affect distribution of common and priority species. Similarly, associations between abundance of pintails and other priority grassland species were generally weak because occurrence of most endemic grassland species was not related to wetland habitat or cropland (Figure 3.2a and 3.2b). Rather, native grassland or other perennial cover and patch size are stronger determinants for endemic grassland bird abundance or nest success (Ribic and Sample 2001, Herkert et al. 2003).

Overall, stronger positive correlations in abundance and species richness between duck and other grassland bird species within high and low density strata were observed compared to associations in areas of moderate duck density. These stratum-specific trends may reflect differences in habitat composition and configuration among duck density strata. Although not statistically significant, high and low strata had greater proportions of native grassland than medium stratum thus may have supported a greater variety of priority and common species. In the low density stratum, suitable habitat other than large expanses of dry cropland or native pasture was limited; consequently, the grassland bird community tended to co-exist in remaining “suitable” areas that contained a greater diversity of habitat types, including wetlands and perennial cover. In contrast, habitats within high duck density stratum were structurally more heterogeneous (i.e., higher beta diversity; Knopf and Samson 1994); ducks and other grassland species may co-exist because suitable habitat characteristics were locally available. Fine scale (stop level) and stratum-specific grassland bird-habitat associations are explored in Chapter 4.

Secondly, priority species richness and abundance were relatively constant among strata (Figure 3.3b); however, differences in priority species abundance were detected within strata. These results suggest that, as expected, local habitat availability for nesting and breeding was an important determinant of community composition for this bird group. Within each duck density strata, priority species most likely inhabited suitable habitat patches.

Additionally, species richness and abundance were greatest in high duck density areas yet differences among strata occurred primarily among wetland-associated species (Figure 3.3a and 3.3c; Appendix B, Table B.4). More wetlands were found in high and medium duck density areas compared to low density areas (Table 3.2). Accordingly, most ducks were encountered in high or medium duck density areas because breeding ducks tended to settle in areas of greatest wetland density (although upland nesting habitat requirements vary among species; Greenwood et al. 1995). Similarly, only individual abundances of wetland-associated species of the common group such as American coot and red-winged and yellow-headed blackbirds were greater in high stratum each year. Among priority species, only Wilson's phalarope was most abundant in high stratum; this shorebird tends to nest within 100-m of wetlands with emergent vegetation or saline lakes with open shoreline (Colwell and Jehl 1994, Dechant et al. 2003b, Jackson 2003). Abundances and species richness of remaining common species were comparable among strata because proportions of suitable habitat classes other than wetlands were similar across strata.

Stratum-specific habitat patterns can be attributed to differences in wetland area (Table 3.2). Although smaller remnant native grassland patches (i.e., < 10 ha; Appendix B, Table B.10) were more common in high stratum, greater areas of wetlands, open waterbodies, and shrubs dissected larger patches of native grasslands, produced higher apparent fragmentation than in low stratum. As a result, I could not reliably separate true grassland fragmentation from habitat heterogeneity. High stratum included greater proportion of forage possibly because DUC's forage conversion program targeted in areas with predicted duck density of > 12 breeding pairs/ ha or higher wetland density (B. Hepworth, DUC, Regina, pers. comm. 2003). Moreover, landowners may have opted to seed cropland to forage because of lower crop prices, poorer quality soils or greater wetland density (less efficient harvest). In contrast, low duck density stratum was a very homogeneous landscape, consisting of either large patches of crop (i.e., Regina Plains) or native pasture (federal, provincial or community pastures) where wetland density is very low. Medium stratum tended to be patchier than low duck density areas as a result of more wetlands and smaller habitat patches.

Mean measured wetland area within 400-m radius was constant between years, even when drought conditions were more severe in 2002 than 2001 (Agriculture and Agri-Food Canada 2002). Waterfowl survey and weather data demonstrate that flooded wetland area declined in 2002 from 2001. Moreover, abundance and species richness of wetland-associated species were generally greater in 2001 than in 2002; in 2002, high duck strata supported greater number of ducks and more wetland associated common species than in 2001. I speculate that concentrations of ducks on remaining full permanent wetlands led to increased duck abundance and greater species richness in high stratum in 2002. Therefore, lack of annual variation in wetland area was a result of inaccurate wetland classification during land cover data ground-truthing. Full and dry wetland basins were not differentiated; dry wetland basins were only omitted from land cover data if basins were tilled or seeded.

Weather patterns may have also affected breeding behaviour and distribution patterns of other species (e.g., lark buntings) resulting in between-year differences in abundance. Below normal 2002 spring temperatures in southern Saskatchewan and spring snowstorms along the migration routes may have delayed bird arrival on the study area by up to 2 weeks compared to 2001 (Environment Canada 2003). As a result, 2002 breeding phenology of some species may have been delayed and courtship behavior may have been more synchronous, resulting in larger, visually conspicuous groups of breeding individuals. Numbers of lark buntings are known to fluctuate greatly from year to year apparently due to local climate variation (Shane 2000, Dechant et al. 2003c). In drought years, these birds are thought to move northward in search of suitable habitat and food (B. Dale, CWS, Edmonton, pers. comm.). BBS trend data corroborate this phenomenon; 2002 index values for lark buntings in BCR 11 were 174 % higher than 2001 values (Downes et al. 2003).

3.5 Conclusions

Duck DSS will be useful for multi-species grassland bird conservation planning in only a general sense, and pintail conservation efforts will not directly benefit most priority species. In the absence of reliable grassland bird abundance or species richness data, conservation actions targeted in areas supporting greater duck species richness will likely support greater grassland bird diversity (species richness or abundance), but species that co-occur are generally associated with wetlands. Yet, substantial amount of unexplained variation between ducks and other grassland birds, particularly between northern pintails and priority species, indicates additional information is required to determine the extent to which ducks and other grassland birds co-occur. Consequently, associations between ducks and other grassland birds have limited utility if used alone to target areas for multi-species management (i.e., specify a level of relative duck abundance and/or species richness that reflects the greatest gain in other grassland bird species abundance and richness) because habitat needs of species of conservation concern may not be met by targeting conservation efforts at specific group (Kerr 1997, Chase et al. 2000, Suter et al. 2001 and Poiani et al. 2001, Lawler et al. 2003).

Priority species richness and relative abundance were similar across the study area because these species may inhabit areas with appropriate habitat attributes and patch sizes within each route independent of predicted duck density, an idea I evaluate in Chapter 4. Distribution and abundance of grassland birds are likely affected by habitat structure (i.e., composition and spatial configuration of habitat patches), social interactions and local predator communities operating at multiple spatial scales, all of which were not measured in this study. Therefore, adequate essential habitat for priority species may not be protected if conservation is focused only in areas of moderate to high wetland density without consideration of surrounding landscape composition or configuration.

CHAPTER 4. LANDSCAPE-LEVEL HABITAT ASSOCIATIONS OF DUCKS AND OTHER GRASSLAND BIRDS IN SOUTHERN SASKATCHEWAN

4.1 Introduction

Loss and fragmentation of breeding habitats due to agricultural practices over the past 3 decades are among the most important ultimate causes of recent population declines of grassland birds in the prairie ecozone of North America (Samson and Knoph 1994, Peterjohn and Sauer 1999, Houston and Schmutz 1999, Ribic and Sample 2001). In southern Saskatchewan, < 20% of native mixed grass prairies remain (Sampson and Knoph 1994, Vickery et al. 1999) and remnant tracts of native grassland are currently threatened by cultivation, over-grazing by livestock and encroachment of exotic plant species (Dale et al. 1997, Davis et al. 1999, Browder et al. 2002).

Historically, conservation of birds in the North American prairie region has focused primarily on waterfowl. Duck density models and landscape-level habitat data are used to direct habitat conservation and management programs for the greatest impact on duck populations. More recently, growing interest in conserving bird species at risk has led to a more integrated approach. Partners in Flight (PIF) have successfully implemented a regional population monitoring and conservation planning framework (e.g., Bird Conservation Regions [BCR]) for multiple land bird species across North America (Carter et al. 2000, Downes et al. 2000). To more fully evaluate relationships between waterfowl and other grassland bird species for which data are lacking, the most important environmental gradients linked with the structure of bird communities must be identified (Rotenberry and Knick 1999).

Processes affecting habitat use by grassland birds interact at multiple scales (Wiens, 1989, Freemark et al. 1995, Stephens et al. 2004). Relationships between species occurrence and abundance and local, micro-site vegetative attributes in the mixed grass prairies have been well studied (Hartley 1994, Davis et al. 1999, Davis and Duncan 1999, Madden et al. 2000, McMaster and Davis 2001). Over the last decade, researchers have been interested in the influence of habitat patch size on grassland species abundance, richness and nest success (Vickery et al. 1994, Herkert et al. 1994, Rotenberry and Knick 1999, Helzer and Jelinski 1999, Herkert et al. 2003). Previous reliable research suggests that densities of some grassland species (e.g., Sprague's pipit, grasshopper sparrow and bobolink; scientific name of birds are given in Appendix B, Tables B.1 and B.2) are positively related to habitat area (i.e., these species appear to be area sensitive; Herkert 1994, Winter and Faaborg 1999, Johnson and Igl 2001, Horn et al. 2002, Davis 2003). Negative effects of habitat fragmentation on reproductive success, survival, and dispersal have been well documented in forest systems (Andrén 1994, Freemark et al. 1995, Donovan et al. 1997) but not in grasslands. Currently, landscape structure (i.e., composition and spatial configuration of surrounding habitat matrices) is thought to affect grassland bird distributions (Andrén 1994, Ribic and Sample 2001, Fletcher and Koford 2002, Bakker et al. 2002) and reproductive success (Herkert et al. 2003, Stephens et al. 2004) in agricultural landscapes, not just local patch or vegetative characteristics.

Despite these important advances, influences of both patch and landscape metrics on bird communities are still relatively unknown, especially in grassland ecosystems (Clark and Nudds 1991, Davis et al. 1999, Helzer and Jelinski 1999, Fletcher and Koford 2002). Understanding effects of landscape pattern (i.e., composition and structure of habitat patches) on the entire grassland bird community may enhance other grassland bird species benefits of habitat programs directed toward waterfowl (Clark and Diamond 1993, Ball 1996).

My general objective was to quantify broad structure at the bird community scale and evaluate landscape features common to both waterfowl and other grassland bird species. Because optimal breeding habitat may be limited, it is critical to gain insight into general patterns of landscape-level habitat use by grassland bird community, particularly species of conservation concern. Moreover, the general bird community structure and the extent to which ducks and priority species co-occur may be strongly influenced by amount and configuration of suitable habitat (Andrén 1994, Coppedge et al. 2001b, Fletcher and Koford 2002, Chapter 3). I predicted ducks and other grassland birds may co-occur at a greater extent in heterogeneous areas that provide a greater complexity of habitat types for a greater variety and abundance of bird species, including waterfowl, than do highly modified areas dominated by summer fallow, cereal, oilseed or other crops (Renken and Dismore 1987). Conversely, some grassland obligates (e.g. Sprague's pipit, chestnut-collared longspur, Baird's sparrow) may be area sensitive (Herkert 1994, Johnson and Igl 2001); thus I predicted these species may not be strongly associated with ducks in landscapes comprised of larger parcels of native grassland (Ribic and Sample 2001, Bakker et al. 2002, Davis 2003).

I evaluated bird-habitat patterns in agricultural and natural habitats by linking stop-level land cover data with bird survey data (Flather and Sauer 1996, Coppedge et al. 2001b). Ordination techniques were used to determine: (1) how bird communities vary with respect to habitat area and spatial configuration at the stop-level and (2) extent of overlap in habitat use by ducks, common and priority bird species. Differences in grassland bird-habitat patterns across duck density strata were also assessed. This information could help to determine whether general management goals for multiple avian grassland species are applicable in different landscapes.

4.2 Methods

Data were collected within the southeastern portion of the Missouri Coteau, southern Saskatchewan in 2001 and 2002. Point count surveys were conducted from late May to early July 2001 and 2002, using a modified BBS protocol. Habitat composition and patch configuration of 10 land cover classes within a 400-m radius from the center of each stop point surveyed in 2001 and 2002 were calculated from digital land cover data using Patch Analyst extension (Version 2.2) of ArcView (Elkie et al. 1999). Detailed descriptions of the study area and field methods are provided in Chapter 2.

4.2.1 Bird-habitat ordinations

To determine which land cover classes and habitat patch variables were associated with individual bird species abundances at the grassland bird community level, I conducted detrended correspondence analysis (DCA) using the computer program PC-Ord (McCune and Mefford, 1999) with a subset (33%; n = 888 stops) of randomly selected, unique stop points. Only abundances of core species common in both years (n = 55 species) were included. Even so, less common species were down-weighted in proportion to their frequency because DCA is sensitive to species that only occur in sites with low species richness; down weighting minimizes their influence on the ordination (Jongman et al. 1998, McCune and Mefford, 1999). Thirty-five outliers (i.e., stops with weighted mean species scores > 2.0 standard deviations based on relative Euclidean distance between samples) were eliminated prior to running DCA (McCune and Mefford, 1999).

To determine which habitat variables were related to variation in the bird community, I used corresponding stop-level habitat (i.e., composition and spatial structure of habitat patches within 400-m radius plots) data based on digital land cover data (See Chapter 2 for details) as a passive environmental data set and calculated Pearson correlation coefficients between each habitat variable and the stop point scores on the DCA axes (Hobson and Bayne 2000). Species-habitat join plots illustrate the degree of association between bird abundance gradients and habitat variables. Species points correspond to the species' optimal position (i.e., most abundant) along environmental gradients. Species situated closer together in ordination space tend to use similar habitats than species positioned further apart. The length and angle of the vector indicate the strength of relationship between the habitat variable and the species scores and DCA axes (McCune and Grace 2002). Species on the edge of the scatter plot are often less common species because they are found in unique environmental conditions (Jongman et al. 1998). In contrast, species at the center of the ordination may be prevalent at two points along the environmental gradients (bimodal response curve), have optimal positions at center of the plot (unimodal response curve) or abundances are unrelated to measured habitat data (Jongman et al. 1998). All default options were selected and coefficients of determination (r^2) were calculated "after-the-fact" (based on relative Euclidean space) to determine the percentage of variation in the bird abundance matrix that was explained by each axis (McCune and Grace 2002). Common and scientific names of bird species corresponding to the American Ornithologists' Union

(AOU) species codes presented in the ordination diagram are given in Appendix B, Table B.2.

To determine specific habitat use patterns for priority (n = 11 species) and duck (n = 10 species) species groups, separate DCAs were performed using count and corresponding habitat data at all stop points where at least one duck or priority bird species was encountered. Because differences in detection probabilities among species may affect priority species-habitat associations, all priority species were classed as conspicuous or inconspicuous and raw counts were corrected using appropriate detection correction factors (i.e., 2.25 for conspicuous species and 2.75 for inconspicuous species; Table 2.2; Appendix A, Table A.5).

To evaluate stratum-specific DCAs, I first combined bird and corresponding habitat data from stop points within high and medium strata into one group (medium/high) because of extensive overlap in species richness and abundance between both strata (Chapter 3). Subsets (50%) of randomly selected, unique stop points from both the low and medium/high strata were used in the stratum-specific ordinations. See Chapters 2 and 3 for detailed descriptions of methods and data analyses.

Despite criticisms of this technique (see reviews by Jackson and Somers 1991 and McCune and Grace 2002), DCA using large sample sizes (> 200 points) are thought to generate stable results and reliably recover important underlying environment gradients in bird abundance data (Patten and Rotenberry 1998). Canonical Correspondence Analysis (CCA) was not used because the variation in the bird community may not be exhibited if critical habitat variables are not included (McCune and Grace 2002, Hobson and Bayne 2000).

4.3 Results

Forty percent (n = 1107) of all stop points surveyed in each year were digitally corrected; most common corrections resulted from conversion of crop to forage or tame pasture and omission of wetlands. Among the subset of re-sampled routes, additional habitat changes were made at 202 (31%) stop points in 2002 due to crop rotations and many flooded wetlands in 2001 became dry and were tilled or hayed in 2002.

4.3.1 General grassland bird-habitat association patterns

The first DCA function explained 23.4% of the variance in the species abundance data (Figure 4.1). This function was significantly positively correlated with habitat heterogeneity index (H'), total habitat patch edge, areas of wetlands, open waterbodies and negatively correlated with mean patch size, mean core area, mean native grassland patch size and core area (Appendix B, Table B.5). DCA function 2 accounted for 13.7% of variation in the bird data and was positively correlated with farmyards and odd areas, and larger patches of native pasture; this function was also negatively correlated with areas of wetlands and croplands.

All core water birds (i.e., ducks, American coot, sora rail and Canada goose); some shorebirds (e.g., marbled godwit, American avocet, killdeer and Wilson's phalarope), song sparrows, red-winged and yellow-headed blackbirds, and Nelson's sharp-tailed sparrows were associated with wetlands in intensively farmed areas in a patchy landscape. Remaining common species were also found in highly heterogeneous landscapes but were mainly associated with farmyards and treed areas (e.g., house sparrow, American robin, mourning dove, warbling vireo, and western kingbird), or larger patches of native pastures (e.g., least flycatcher or brown-headed cowbird). In contrast, priority species (e.g., Baird's sparrow, chestnut-collared longspur, sprague's pipit, bobolink and lark bunting) tended to be associated with larger patches of dry native pastures. Savannah sparrows and horned larks were also moderately related to larger parcels of cropland or native prairie. Finally, species grouped near the center of the join plot tended to be common through out a range of habitat conditions (i.e., western meadowlark and horned lark) or were not correlated to either environmental gradient (i.e., common snipe, Nelson's sharp-tailed and vesper sparrows, willet, upland sandpiper, American crow and Swainson's hawk).

4.3.2 Duck community-habitat associations

A total of 825 stops points was used and the first 2 DCA functions explained 59% of the variance in the duck species data (30%, 29% respectively; Figure 4.2, Appendix

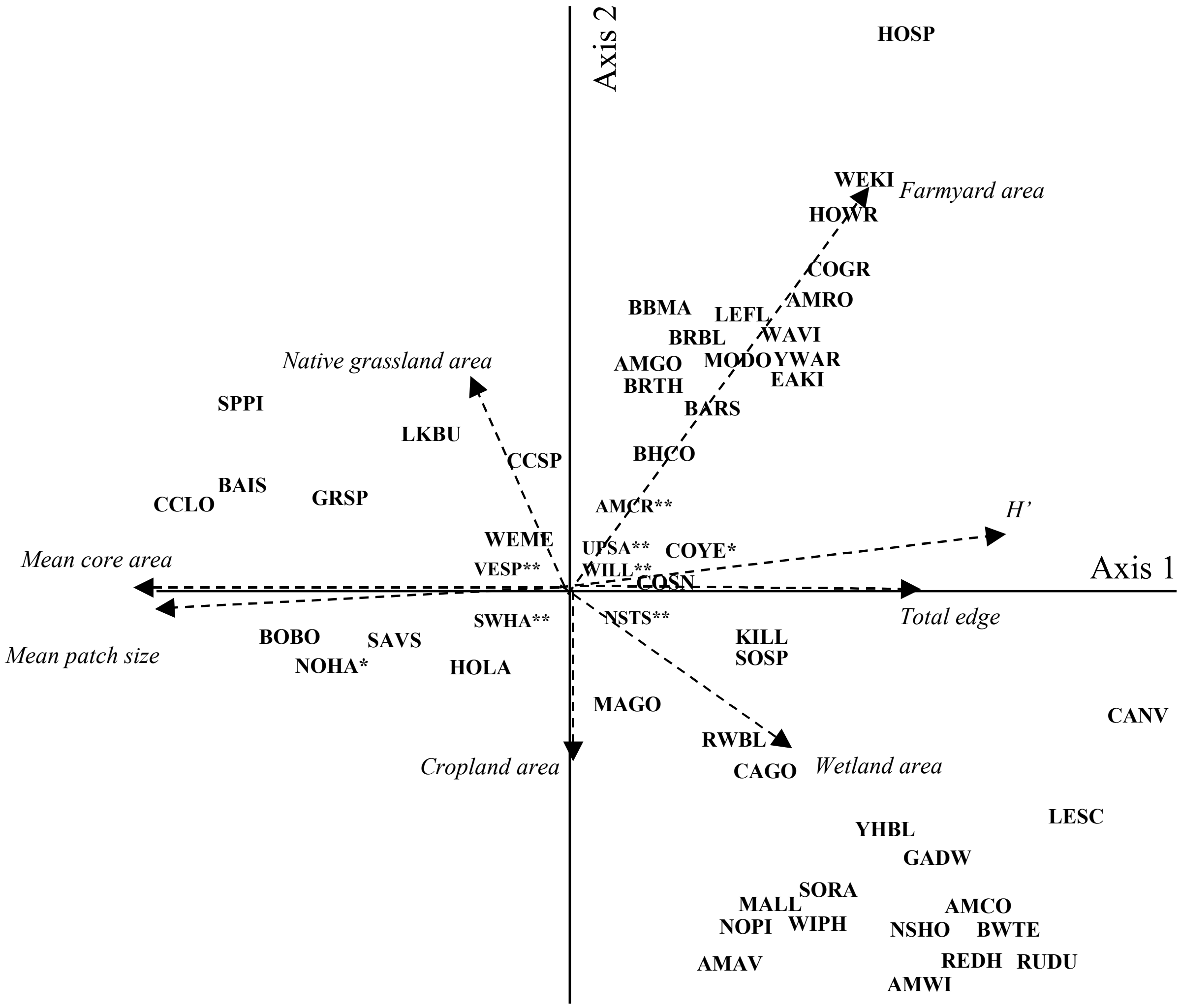


Figure 4.1. Two-dimensional plot illustrating results of a detrended correspondence analysis (DCA) at the grassland bird community level. AOU codes for each species are given in Appendix B, Table B.2. Species located closer together have greater similarity in habitat requirements than those placed farther apart. Vectors represent strength and direction of the correlation between habitat variables and each DCA axis. DCA was performed on species-level bird abundance data obtained from a random sample of 33% of all unique 2001 and 2002 survey stop points. All species are strongly associated (P < 0.01) with at least one of two principle DCA functions except species with single * are significantly correlated (P < 0.05) and species with double ** are not.

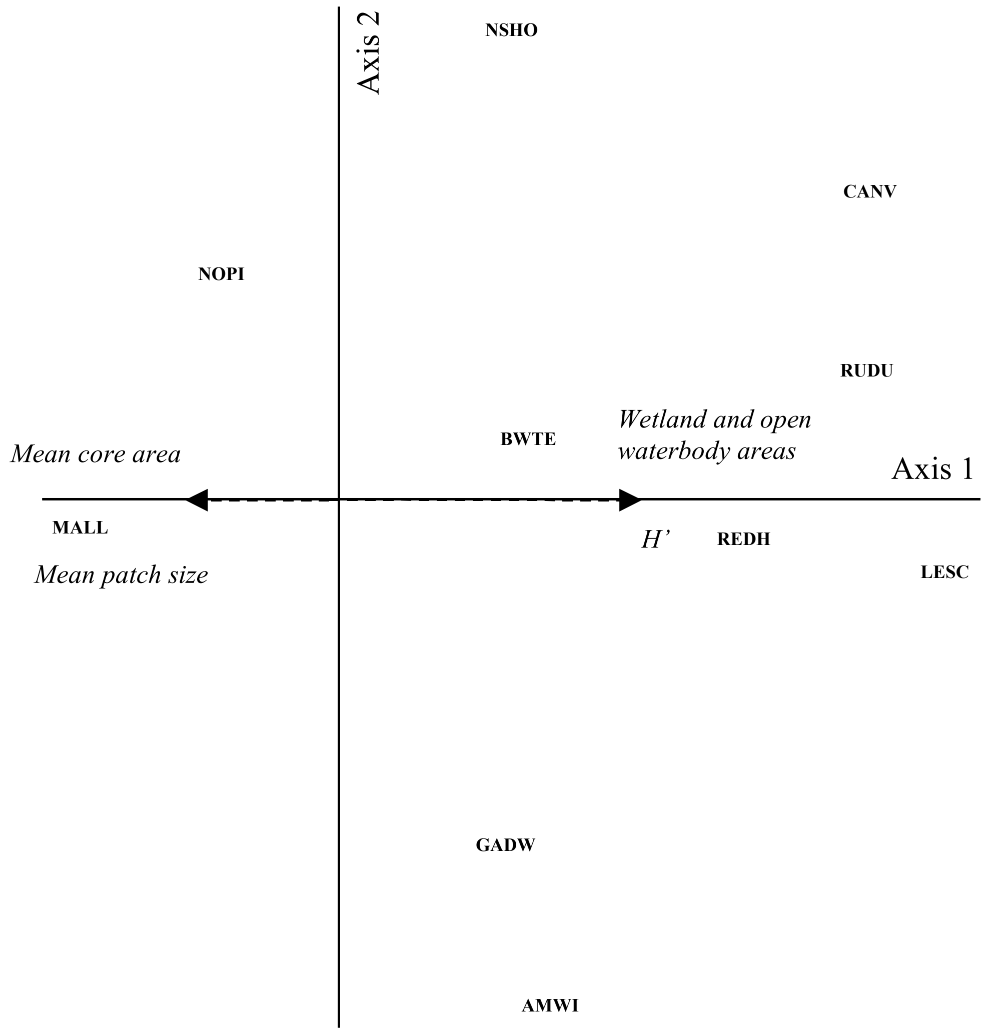


Figure 4.2. Two-dimensional plot illustrating results of a detrended correspondence analysis (DCA) for ducks (n = 10 species). AOU codes for each species are given Appendix B, Table B.2. Species located closer together have greater similarity in habitat requirements than those placed farther apart. Vectors represent strength and direction of the correlation between habitat variables and each DCA axis. DCA was performed on species-level bird abundance data obtained from all unique 2001 and 2002 survey stop points where counts of duck species ≥ 1. All species displayed are significantly correlated (P < 0.01) with at least one of two principle DCA functions.

B, Table B.6). DCA function 1 was positively correlated with wetlands, open waterbodies, H’, total edge and forage and negatively correlated with mean core area,mean patch size and cropland. All correlations between measured habitat variables and DCA function 2 were non-significant (all Ps > 0.05). DCA 2 was weakly positively associated with larger parcels of native or tame pasture and farmyards and weakly negatively correlated with mean core area, number of habitat patches, cropland and treed area. The third DCA function was positively correlated with larger, more uniform patches of tame pasture.

Northern pintails and mallards were less strongly related with wetlands compared to other ducks. Pintails were most strongly associated with low standing cover such as crop, tame pasture or larger tracts of native grasslands and mallards were associated with larger patches of cropland. Northern shovelers were moderately correlated with wetlands embedded in larger parcels of native or tame pasture, whereas gadwalls and American wigeons were most strongly related to patchy landscapes interspersed with wetlands, trees and uniform parcels of crop. Canvasbacks, lesser scaups, ruddy ducks, and redheads were all moderately related to wetlands and open waterbodies in heterogeneous landscapes with a higher proportion of forage. Finally, blue-winged teal abundance was only weakly associated with patchy areas dominated by wetlands.

4.3.3 Priority species community-habitat associations

DCA was based on 1,191 stop points and abundance data that were corrected for unequal detection probabilities between conspicuous and inconspicuous species (Table 2.2, Figure 4.3). The first DCA function accounted for 16.7% of explained variance and was moderately positively associated with landscapes containing wetlands, open waterbodies and cropland; this axis was negatively correlated with larger patches of native grasslands interspersed with shrub (Appendix B, Table B.7). The second DCA function accounted for 23.3% of variation in priority species and was positively correlated with cropland, mean habitat patch and core area and negatively correlated large patches of native grasslands, H’, number of habitat patches, total edge, shrubs and trees.

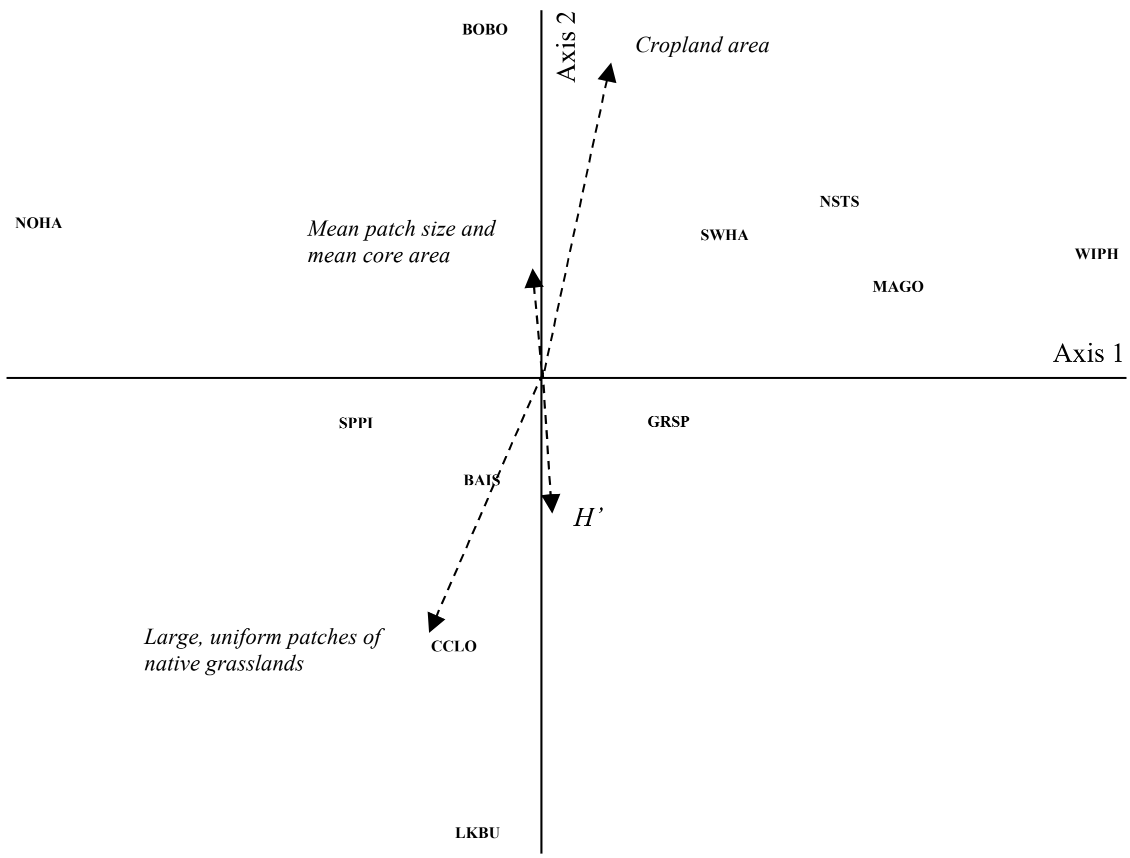


Figure 4.3. Two-dimensional plot illustrating results of a detrended correspondence analysis (DCA) for priority species (n = 11 species). AOU codes for each species are given in Appendix B, Table B.2. Abundance estimates have been corrected for detection deficits based on distance sampling for conspicuous and inconspicuous species. Species located closer together have greater similarity in habitat requirements than those placed farther apart. Vectors represent strength and direction of the correlation between habitat variables and each DCA axis. DCA was performed on species-level bird abundance data obtained from all unique 2001 and 2002 survey stop points where counts of priority species ≥ 1. All species displayed are significantly correlated ($P < 0.01$) with at least one of two principle DCA functions.

Northern harriers and Sprague's pipits were both strongly correlated with larger tracts of dry, native grasslands in grassland dominated landscapes, whereas bobolinks tended to occur in large patches of dry cropland. In contrast, Wilson's phalaropes and marbled godwits tended to occur near wetlands in more heterogeneous cropland areas while Swainson's hawks and Nelson's sharp-tailed sparrow had a propensity for larger patches of cropland interspersed with wetlands. Lark buntings and chestnut-collared longspurs were typically associated with larger parcels of native grassland in an otherwise patchy landscape that included shrubs, trees and tame pasture. Finally, Baird's and grasshopper sparrows were found near the center of the ordination because they were most abundant at points midway along each environmental axis, suggesting these species could inhabit a wider range of habitat conditions compared the other priority species.

4.3.4 Stratum-specific bird-habitat associations

Only 51 species were recorded at 439 randomly selected stop points in low duck density strata. Sora rail, ruddy duck, redhead, and canvasback were not encountered in this subset of stops. Most grassland bird species including ducks, shorebirds, priority species and other common species were most strongly associated with heterogeneous landscapes consisting of a variety of upland and wetland habitats. Only northern harrier, bobolink, horned lark, and savannah sparrow commonly occurred in dry cropland (Appendix B, Figure B.1; Table B.8).

Medium/high DCA was based on 955 randomly selected stops points in medium or high strata and all 55 core species were encountered. Most priority species tended to occur in large, dry, uniform habitat patches dominated by either forage or native grasslands with scattered shrubs (Appendix B, Figure B.2; Table B.9). In contrast, all duck species and most wetland-associated species (e.g., American coot, yellow-headed and red-winged blackbirds, sora rail, killdeer, Wilson's phalarope) were most strongly associated with wetlands in cropland. Remaining common species (e.g., common grackle, western kingbird, house wren, yellow warbler) were most numerous in patchy landscapes consisting of farmyards, treed areas, tame pastures, wetlands, and open waterbodies.

4.4 Discussion

Little habitat overlap among ducks, common species, and priority grassland bird species was apparent at the community level. In Chapter 3, duck abundance and species richness were greatest in high duck stratum inferring that wetland area was an important environmental factor influencing where ducks settle on the landscape; priority grassland species abundance and species richness were relatively constant among strata indicating the majority of these species were occupying suitable habitat independent of wetland area. As predicted, most priority grassland bird species inhabited grassland-dominated sites in areas with low wetland densities, whereas the distribution and abundance of ducks and other water birds were most strongly influenced by local wetland area. Among priority birds, Wilson's phalaropes and to a lesser extent, marbled godwits shared similar heterogeneous, wetland-dominated landscapes as ducks; suggesting conservation of critical waterfowl habitat would benefit only few species of concern. "Farmyard" species were primarily birds native to the prairie region yet were no longer restricted to river valleys or other isolated areas with trees; they predominated areas with trees or buildings (e.g., barn swallows, mourning doves, house sparrows, and magpies) or were attracted to cattle (e.g. brown-headed cowbirds). In southern Saskatchewan, the majority of trees remaining on the landscape have been planted as windbreaks or fencerows near or in farmyards; thus, this phenomenon may have contributed to their clumped distribution. Finally, several common species were able to use a greater range of habitat types (i.e., habitat generalists) or may have been related to other habitat variables not included in the analysis.

In this study, duck habitat-use patterns are predominately affected by wetland area and patch size at the stop-level although environmental gradients accounted for little variation in duck distribution. Mallards, and northern pintails were most strongly associated with larger habitat patches compared to northern shovelers, blue-winged teal, gadwalls and American wigeons that tended to inhabit wetlands in more diverse landscapes. Mallard and northern pintails are early nesters and may have been attracted to shallow, temporary or seasonal ponds typically found in flat cropland or seeded pastures because these wetlands are the most nutrient rich early in the breeding season (Krapu et al. 1997). Pintails are known to nest in cropland stubble but mallards generally prefer perennial cover for nesting habitat (Prodrunzy et al. 2002, Greenwood et al. 1995). It is possible mallards may have nested in suitable cover at some distance beyond the 400-m radius plots. In comparison, blue-winged teal, northern shovelers, gadwall and American wigeons nest later in the breeding season and have a greater affinity for semi-permanent wetlands found in a variety of habitat types during pair bonding, egg-laying and incubation periods (Krapu et al. 1997). Finally, diving ducks (e.g., redheads, canvasbacks, ruddy ducks and lesser scaup) were most strongly associated with permanent wetlands and less related to surrounding upland habitat possibly because these species are primarily benthic feeders and predominately nest over water; therefore were less reliant on suitable upland nesting habitats (Krasowski and Nudds 1989, Maxson and Riggs 1996). Moreover, these species likely settled on semi-permanent wetlands with sufficient emergent cover undisturbed by grazing cattle in idle pastures or forage fields (Yerkes 2000).

Although ducks appear to use habitats that correspond to general habitat requirements, additional research is required to understand how landscape composition and structure affect waterfowl habitat use and productivity (Clark and Nudds 1991). Regional differences in upland habitat and wetland quality, agricultural practices, predator communities, and environmental conditions (i.e., drought cycles) are factors that affect waterfowl settling patterns and nest success (Clark and Diamond 1993, Sovada et al. 2000, Krapu 2000, Reynolds et al. 2001, Austin 2002, Mack et al. 2003). Regardless, most waterfowl biologists speculate that landscapes containing adequate wetland density and larger, contiguous tracts of grassland or perennial cover will improve waterfowl recruitment (Clark and Diamond 1993, Greenwood et al. 1995, Sovada et al. 2000, Reynolds et al. 2001).

Response of many grassland endemic bird species to landscape-level habitat characteristics appears to vary regionally and is often scale dependent (Johnson and Igl 2001, Horn et al. 2002). This study illustrates that priority species abundances are most affected by habitat heterogeneity and grassland area at the stop-level. Because the main environmental axes accounted for relatively low amounts of variation, local variation within and among habitats (i.e., vegetation composition and structure) may have also affected the distribution patterns of this group. As predicted, Sprague’s pipits, chestnut-collared longspurs, northern harriers, and lark buntings were more abundant in areas of larger, drier native grassland patches in both the community and group-specific levels. My findings are consistent with recent evidence that suggests these species have large area requirements or that abundance or productivity are positively related to native grassland patch size or amount of grassland in the surrounding landscape (Davis et al. 1999, Herkert et al. 1999, Johnson and Igl 2001, McMaster and Davis 2003, Davis 2003, Dechant et al. 2003c and 2003d).

Bobolinks are known to prefer moderately tall, dense vegetation without shrubs, typical of hayland or grassland habitats (See review by Dechant et al. 2003e), yet I found bobolinks were most abundant in large, uniform patches of cropland. Bobolink occurrence in South Dakota was primarily related to local vegetation attributes (Bakker et al. 2002), but was positively correlated with patch area or inversely correlated with perimeter-area ratio in some mid-western states (Herkert et al. 1994, Helzer and Faaborg 1999, Johnson and Igl 2001, Horn et al. 2002). In Wisconsin, bobolink density was positively affected by areas of hay and grassland within 800-m of survey transects (Ribic and Sample 2001). Therefore, large grain fields in the Missouri Coteau may have been structurally more attractive to bobolinks than forage and native pastures of similar size and configuration (Figure 4.3).

I found Baird's and grasshopper sparrows were associated with larger patches of native prairie in the general community context, but they appeared less affected than other priority species by the measured environmental variables. Baird's sparrows do not consistently exhibit area sensitivity and may inhabit a variety of habitat types although density and productivity may vary among and within habitats (Dale et al. 1997, Davis and Duncan 1999, Johnson and Igl 2001, McMaster and Davis 2001, McMaster and Davis 2003, Davis 2003). Grasshopper sparrows generally exhibit area sensitivity but may also be influenced by surrounding landscape or local vegetative factors (Winter and Faaborg 1999, Johnson and Igl 2001, Ribic and Sample 2001, Horn et al. 2002, Bakker et al. 2002, Davis 2003). Therefore, Baird's sparrow habitat preferences may be more flexible than other priority species, using other habitat types when preferred habitat (larger patches of native prairie) is unavailable and grasshopper sparrows may be keying on additional habitat attributes other than those measured in this study.

Similar to ducks, Wilson's phalaropes and marbled godwits were most strongly related to amounts of wetland at both the community level and group-specific level. Wilson's phalaropes tend to nest in wetland margins with emergent vegetation, wet meadows or upland grasslands adjacent to wetlands (Colwell and Jehl 1994, Dechant et al. 2003b, Jackson 2003). However, Jackson (2003) found phalaropes occasionally (i.e., 30% of found nests) nested away from wetland margins in lightly or moderately grazed native pastures. Marbled godwits strongly avoid tilled cropland and prefer to nest away from wetlands in large tracts of short, sparse to moderately vegetated grassland that include a variety of wetland types and salinity levels (i.e., ephemeral to semi-permanent; Ryan et al. 1984, Gratto-Trevor 2000). Moreover, upland habitat may provide important feeding and loafing sites in drought years (Ryan et al. 1984). Thus, marbled godwits may not have been as strongly associated with ducks compared with Wilson's phalaropes because of their stronger affinity for grassland habitats during the breeding season (Figures 4.1 and 4.3).

Finally, habitat associations of some species were questionable. In this study, Nelson's sharp-tailed sparrows were mainly detected on fence lines or perched on taller vegetation along habitat edges (e.g., ditch vegetation); thus associated habitats may not represent general habitat use (Dechant et al. 2003f). This sparrow is a secretive and an irregular singer; information on area and habitat requirements is limited. Although this species prefers nesting near fresh wetlands with dense emergent vegetation, this bird is also known to nest in cropland in Iowa (Dechant et al. 2003f). In comparison, Swainson's hawk abundance was not strongly related to important community-, group or stratum-level habitat gradients perhaps because this hawk was most often detected while flying (i.e., may not have used associated habitats for breeding or foraging habitats). However, the small landscape scale (i.e., 400-m radius) relative to large home ranges (range 6.2-27.3 km^2) that include a variety of habitat types such as open grasslands and scattered trees or shrubs may have accounted for the apparent general distribution of this raptor (Dechant et al. 2003g). Moreover, Swainson's hawk forages in both cropland and natural areas in highly cultivated areas (Groskorth 1995) and therefore may have been more common than other priority species in non-native habitats.

Grassland bird community structure was influenced by landscape composition and configuration. In low stratum, few species were associated with large, dry patches of cropland whereas the majority of the avian community co-existed along a relatively narrow range of environmental conditions dominated by large parcels of native grassland surrounded by patchy landscapes (including all landcover classes except cropland), suggesting species were concentrated in limited areas of available suitable habitats. Ducks and other wetland-associated species were infrequently encountered because of the paucity of wetlands and hence were not strongly associated with other measured habitat variables. Moreover, cropland areas, specifically those cultivated using continuous cropping techniques are ecological traps, so species that commonly used cropland habitats in low density stratum, such as most duck species, bobolink, horned lark and savannah sparrow, may not be reproductively successful (Prodruzny et al. 2002, B. Dale, pers. comm). In comparison, priority and duck species in medium or high strata tended not to co-exist at the stop-level because greater habitat heterogeneity enabled a greater diversity of species to occupy suitable habitats within a relatively small area throughout these landscapes (i.e., higher beta diversity; Samson and Knopf 1994. Most ducks and other wetland-associated species including Wilson's phalarope (priority species) inhabited wetlands that tended to occur in cultivated areas whereas remaining priority species inhabited the largest contiguous parcels of native grassland available in these landscapes.

I recognize bird-habitat association patterns may arise, in part, because of spatial autocorrelation of bird abundances. Spatial autocorrelation refers to the propensity for stops that are in closer proximity to exhibit physical or morphological characteristics that are more similar than expected for random pairs of points (Legendre and Fortin 1989, Legendre 1993, Fortin et al. 2002, Lichstein et al. 2002a). Preliminary analysis with Moran's I statistic and semi-variance (Fortin et al. 2002) indicated abundances of both generalists and grassland specialists were positively correlated among stops that were separated by < 800 m to several kilometers, suggesting individuals were distributed in a non-random fashion (clumped or patchy). Large-scale trend (i.e., true environmental gradients) or fine-scale (i.e., true spatial autocorrelation) processes such as conspecific attraction, territoriality, limited dispersal, and population density may explain this spatial dependence. Often habitat and space are confounded where by habitat is spatially autocorrelated, producing a spatial clustering of species using the patchy habitat (Legendre 1993, Fortin et al. 2002, Lichstein et al. 2002b). If the abundance data are spatially autocorrelated, each sample replicate may not be independent, so standard errors associated with correlations between habitat attributes and bird abundance data will be over optimistic (Legendre 1993). Nevertheless, I found patterns of bird abundance and associated habitat variables were consistent based on systematic sampling (i.e., using every 3rd point) and random sampling down to 25% of total sample size where effects of finer scale spatial dependence among adjacent points should be minimal. Additionally, analysis of autocorrelation among sample pairs were consistent with Lichstein et al. (2002b); suggesting that survey points separated by 500 m were found to be independent sample units for most avian species. Therefore, I am confident the relationships represented by the ordination diagrams are robust.

4.5 Conclusions

In general, ducks and priority landbird species do not co-exist at a local scale. Protection and conservation of wetlands in an agricultural setting will directly benefit ducks and other wetland-associated species such as Wilson's phalarope but adequate critical habitat for several priority species may not be protected if regional scale conservation is focused mainly in areas of high wetland density. This study highlights the need for habitat conservation programs independent of duck initiatives directed specifically at area sensitive grassland obligates such as Sprague's pipit, chestnut-collared longspurs, or lark buntings. Currently, conservation of large, contiguous tracts of habitat is thought to increase abundance (Helzer and Jelinski 1999, Bakker et al. 2002) nesting success (Greenwood et al. 1995, Winter and Faaborg 1999, Sovada et al. 2000, Reynolds et al. 2001, Herkert et al. 2003, Stephens et al. 2004) of ducks and other grassland birds, especially area sensitive species (Winter and Faaborg 1999, Davis 2003).

Landscape context must be considered when designing effective conservation strategies aimed at both ducks and other grassland species of conservation concern. In homogeneous landscapes (i.e., low stratum) dominated by larger, contiguous tracts of native pasture (e.g., community pastures), programs restricted to areas of high quality wetlands adjacent to larger tracts of native prairie will likely support habitat requirements for a larger complement of the grassland bird community inhabiting these regions. In contrast, heterogeneous landscapes such as in medium/high strata, habitat managed within a regional context (e.g., township level) will most certainly include a range of available habitat types, and patch sizes suitable for a variety of grassland species, including ducks and most grassland endemics (Freemark et al. 1995, Herkert and Knoph 1998, Vickery et al. 1999). Protection and conservation of largest remaining tracts of native pasture (e.g., restoring cropland to tame pasture to reduce grazing pressure) should be a high priority.

CHAPTER 5. SYNTHESIS

Many grassland bird species have experienced population declines over the past 30 years largely due to loss, fragmentation and degradation of native grassland habitat. Although avian conservation on the prairies has been primarily directed at specific bird groups, particularly ducks, recent international partnerships have shifted focus from single taxonomic groups to multiple bird species and landscape-level conservation. Prairie landscapes are dynamic systems shaped by drought cycles and intermittent fire and grazing disturbances, and more recently agricultural practices. In turn, these processes strongly influence habitat structure, food resources, predators and alternate prey communities (Herkert and Knopf 1998, Sovada et al. 2000). Bird species that share common habitats such as wetlands, native pastures and shrubland may be affected in similar ways by these processes, producing co-variation in patterns of bird abundance (Ball 1996, Johnson 1996). Consequently, identifying relationships between grassland birds and associated habitat attributes is an important step toward effective conservation programs.

In Chapter 3, I evaluated the premise that duck DSS is a useful guide for community-level grassland bird conservation, including species of conservation concern. I found that duck abundance and species richness were weak to moderately strong indicators of common and priority species abundance and richness. Contrary to my expectations, northern pintail was not a reliable indicator species of other grassland obligates; abundance was largely unrelated to priority species richness and abundance because habitat variables such as native grassland patch size rather than wetlands affected distribution of these species. Consistent with my predictions, I found more birds of more species in areas of high and medium duck density because these areas contained a greater variety of habitats, including wetlands, forage and shrubs.

Species that tended to co-occur with ducks were primarily wetland-associated. More importantly, priority species abundance and richness were comparable across strata suggesting these species inhabited suitable habitat independent of predicted duck density or suitable duck habitat. Thus I suggest duck species are important umbrella taxa for other wetland-associated species and some common species that use habitats adjacent to wetlands (e.g., shrub and forage) but conservation strategies directed at ducks will yield limited benefits for priority species with strong affinities for native prairie.

In Chapter 4, I examined grassland bird community structure and associated habitat characteristics. I found a distinct spatial separation among ducks, common and priority species. At the three levels (i.e., community-, group- and stratum-level), ducks and most priority species did not inhabit common habitats. Patch size and habitat configuration were strong determinants of priority species abundance; most priority species were more common in larger, more uniform parcels of native prairie in the absence of wetlands. Subsequent analysis of priority species mean abundances between stops with large contiguous blocks of native pastures (i.e., low proportion of shrub and wetlands) and large tracts of patchy native pastures (i.e., contain wetlands or shrubs) confirmed these species were more abundant in contiguous native prairie with low wetland or shrub components (Appendix B, Table B.10). Although fewer priority species were present at sites with remnant grassland patches (i.e., < 10 ha), recent evidence suggests smaller parcels of remnant prairie may also be of conservation value (Villard 1998, Bakker et al. 2002, Davis 2003). In contrast, ducks and other wetland-associated species were commonly associated with wetlands regardless of surrounding habitat characteristics. Of the priority group, only Wilson's phalarope and to a lesser extent, marbled godwit were commonly associated with ducks. Only mallard and northern pintails appeared to have affinities for larger habitat patches. The remaining common species usually occurred at stops dominated by mixed habitat composed of trees, farmyards or native pastures.

The extent to which ducks and priority species co-occur depends on the composition and configuration of the surrounding landscape. In Chapter 4, I determined ducks and priority species generally do not co-occur at the stop-level in highly heterogeneous landscapes (e.g., medium and high strata) but that suitable habitats for both groups may exist in close proximity because diverse habitats were distributed throughout these areas. In comparison, I found ducks and other wetland-associated common species were less abundant in homogeneous landscapes (e.g., low stratum) because suitable wetlands were scarce in these areas. Thus areas where ducks and priority species could co-exist were restricted to a small proportion of sites containing wetlands adjacent to contiguous tracts of native pasture.

This study had several major limitations. First, point counts within randomly placed roadside survey routes were assumed to represent habitat characteristics indicative of the local landscape (Hanowski and Niemi 1995). In both years, areas of cropland, pasture and forage were over-sampled because regular grid road network existed thoughout highly cultivated areas whereas areas of native grassland, shrubs and saline wetlands tended to be under-represented because public access through larger tracts of native pasture was restricted. Moreover, roads created breaks in habitat continuity and were associated with fence and power lines. Thus, species that avoid roadways or used under-represented habitats (e.g., Sprague's pipit, Baird's, Nelson's sharp-tailed and clay-coloured sparrows) were underestimated whereas species attracted to cultivated areas (e.g., horned lark) or roadside areas (e.g., western meadowlark savannah and vesper sparrows) were overestimated (Rotenberry and Knick 1995, Sutter et al. 2000). On the other hand, roadside surveys allowed for a large number of well-separated sample points to be collected in a variety of habitat types across a relatively large area. To balance data collection efficiency against reliability of results, survey routes excluded main grid roads with wide shoulders and included secondary gravel and dirt trails when possible (Sutter et al. 2000). Preliminary analysis showed that road width and development (dirt trail vs. primary grid road) were correlated but had little effect on abundance or species richness estimates.

Second, all birds detected by sight and sound were recorded but breeding status of territorial species was not determined. I was able to quantify habitat associations but could not evaluate habitat quality. In theory, populations at low density are able to consistently select habitats that maximize individual fitness; thus populations in "high quality" habitats are generally more stable than populations occupying lower quality habitats (Fretwell and Lucas 1972, Clark and Weatherhead 1987, Bollinger and Gavin

1989, Bernstein et al. 1991). Individuals move into secondary habitats when potential fitness in primary habitats declines due to density dependent factors (e.g., limited nest sites) or intra- or inter-specific competition for resources (e.g., food, cover, mates). However, high bird abundance or density does not necessarily reflect greater habitat quality (Van Horne 1983). Intra-specific competition for limited resources or favourable habitat may lead to a surplus of non-breeding subordinates or juveniles inhabiting poor habitat at moderate or higher densities. Without productivity estimates (e.g., nest density, nest success, fledgling survival), it is difficult to identify characteristics of higher quality habitat patches (Bollinger and Gavin 1989,Vickery et al. 1992, Pulliam 1996, Herkert et al. 2003, Davis 2003).

Third, landscape level land cover data used to derive bird-habitat patterns are coarse-grained habitat information; vegetation structure and composition were assumed to be uniform within and among the same habitat patches but these were not assessed. Grazing pressure affects vegetation structure (e.g., stand height, litter depth, proportion of forbs etc.) and may have influenced priority species occurrence and abundance in native or tame pastures (Johnson 1996). In this region structurally diverse grain, pulse, and oil seed crops (e.g., wheat, barley, peas, oats, canola, and flax); and summer fallow (i.e., no standing cover) were all classified as “cropland”. Similarly, vegetative composition of forage and tame pasture may differ among fields (i.e., proportions of alfalfa and/or grass species). Consequently, the bird community will not respond equally to all “cropland”, “tame pasture” or “forage”.

Finally, I recognize events on wintering and stopover sites (i.e., non-breeding areas) may also have important, although relatively unknown consequences on grassland bird populations. Two-thirds of grassland species encountered including some duck and most priority species over winter in Mexico, Central and South Americas (Herkert and Knopf 1998); thus habitat loss, fragmentation or degradation (e.g., tropical deforestation or grassland destruction); predation, weather events and food supplies in these areas may have limiting or regulatory effects on breeding populations.

My results have implications for conservation of grassland bird habitat in the Missouri Coteau. In general, Ducks Unlimited Canada is the primary provider of waterfowl habitat conservation programs to the Prairie ecozone. Field offices target habitat conservation (e.g., land purchase or easements) or enhancement (e.g., forage conversion) programs across the prairie pothole region in areas of ≥ 12 duck pairs per km^2 and consisting of at least 30% perennial cover. Since the majority of high duck density strata (i.e. > 15 pairs per km^2) in my study area falls within the DUC target areas, conservation efforts in these areas will benefit wetland-associated species such as Wilson's phalarope or marbled godwits and some grassland species. However, actions taken for some duck species may have deleterious effects for other grassland species (Landres et al. 1988, Simberloff 1998). Hayland may attract nesting ducks (Reynolds et al. 2001) and some songbirds (Best et al. 1997, Davis and Duncan 1999, Davis et al. 1999, McMaster and Davis 2001), although productivity (e.g., nest and chick survival) is low during haying operations in some years (Bollinger et al. 1990, Dale et al. 1997). The Greencover Canada program, similar to Canada's previous Permanent Cover Program and the Conservation Reserve Program (CRP) in the United States, may have long lasting effects for ducks and other wildlife but may not support viable populations (i.e., function as sink habitat) of some grassland species (Johnson and Schwartz 1993, Klute et al. 1997, McCoy et al. 1999 but see Koford 1999). Further, protection and restoration of woody shrubs may provide attractive nesting habitat for several duck species and some songbirds (e.g., common yellowthroat, clay-coloured sparrow; Arnold and Higgins 1986, Madden et al. 2000, Davis and Duncan 1999, Mack 2003) but may repel grassland obligates such as Sprague's pipit, chestnut-collared longspur or loggerhead shrike that require open grassland habitats to forage or breed (Johnson 1996, A. Didiuk, CWS, Saskatoon, pers. comm).

This study highlights the need for conservation actions designed specifically for grassland obligates such as Sprague's pipit, Baird's sparrow, chestnut-collared longspur, grasshopper sparrow, lark bunting, and northern harrier. Conservation and management of large parcels of contiguous native prairie with few shrubs or wetlands will certainly increase abundances of priority grassland obligates, especially in the Missouri Coteau. However, conservation actions designed to protect or enhance suitable habitat for both ducks and priority species should be focused in areas of moderate to high duck density where landscape composition and configuration is varied and suitable habitats for both groups are in close proximity (Renken and Dinsmore 1987, Herkert and Knoph 1998, Vickery et al. 1999). In these areas, I suggest managers attempt to conserve remaining contiguous native tracts and improve patchy native parcels (e.g., employ rotational grazing systems or prescribed fire treatments to reduce shrubs, control exotic plants and restore natural plant diversity and successional stages). In sum, a mosaic of habitat types, including wetlands, open and patchy (i.e., containing shrubs and/ or wetlands) native pastures will ultimately increase diversity of the entire grassland bird community (Johnson 1997, Madden et al. 2000, Naugle et al. 2000)

The Missouri Coteau Initiative, led by a multi-agency board (e.g., Prairie Conservation Action Plan, DUC, Nature Conservancy of Canada, CWS, Saskatchewan Watershed Authority and Nature Saskatchewan), is dedicated to habitat stewardship for the benefit of both landowners and wildlife in southeastern Saskatchewan. For example, DUC focuses conservation actions towards large tracts of remnant native prairie in areas of various duck density potential (B. Hepworth, DUC, Regina, pers. comm). Privately-owned native cover is secured through conservation easements and managers work directly with producers and community groups, and pasture managers to promote sustainable grazing strategies and delay hay cutting until after peak duck breeding period; and improve existing pastures by restoring cropland to tame pasture or forage adjacent to native pastures (B. Hepworth pers. comm). These strategies are compatible with habitat needs of many grassland bird species of conservation concern (Bakker et al. 2002, Stevens et al. 2003, Herkert et al. 2003, Davis 2003).

Few studies have examined the relationship between the grassland bird community and local habitat structure across an agricultural mosaic within the mixed grass prairie; the value of remaining grassland habitat to grassland birds is not well known (Coppedge et al. 2001b, Fletcher and Koford 2002, Bakker et al. 2002). Accumulating evidence suggests a serious disconnect among bird abundance, nest density, nest success and productivity (Van Horne 1983, Winter and Faaborg 1999, McCoy et al. 1999, McMaster and Davis 2003, Herkert et al. 2003). Long-term demographic studies (e.g., fecundity, adult and juvenile survival, dispersal rates) are needed to reliably assess quality of available grassland patches of various sizes, shapes and spatial configurations (Herkert and Knoph 1998, Johnson and Igl 2001, Winter and Faaborg 1999, Davis 2003). Further, productivity of priority species on lands enrolled in permanent cover programs in southern Saskatchewan should be assessed (McMaster and Davis 2001). Finally, potential impacts of shrub and wetland areas imbedded in larger tracts of native grassland may have on habitat use or productivity of priority grassland birds should also be determined (Davis and Duncan 1999, S. Davis, CWS Regina, per. comm).

Mounting evidence indicates that patterns of avian species distribution and population dynamics are affected by mechanisms (e.g., area sensitivity, brood parasitism and predation) that operate at different spatial and temporal scales (Freemark et al. 1995, Donovan et al. 1997, see reviews by Mazerolle and Villard 1999, Fauth et al. 2000, Stephens et al. 2003). Presently, features in a landscape at scales larger than patch level (i.e., landscape context) are thought to affect habitat use and productivity of grassland birds (Andrén 1994, Johnson 1996, Donovan et al. 1997, Fauth et al. 2000, Fletcher and Koford 2002, Lichstein et al. 2002a, Stephens et al. 2003). Yet, there is no consensus as to the extent of "landscape scale"; an incorrect choice of spatial scale(s) can result in misleading insights into larger-scale ecological processes (Mitchell et al. 2001, Stephens et al. 2003). Moreover, the relative importance of different scales may vary according to the proportion of suitable habitat in the landscape and the regional context (Flather and Sauer 1996, Donovan et al. 1997, Lichstein et al. 2002a, Stephens et al. 2004). Consequently, defining appropriate landscape scale(s) at which to validate habitat associations for multiple species conservation would be helpful (Freemark et al.1995, Herkert and Knopf 1998, Vickery and Herkert 2001, Lichstein et al. 2002a).

Finally, additional work is needed to determine whether and how wintering ground events contribute to overall population declines (Vickery et al. 1999). Techniques such as stable isotopic tracing or genomics may be valuable tools to identify as yet unknown over-wintering and stopover locations for many grassland species and focus research and conservation measures in critical areas (Hobson et al. 2001).

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APPENDIX A: USING DISTANCE SAMPLING TO EVALUATE DETECTION PROBABILITIES OF GRASSLAND BIRDS

A.1 Introduction

Reliable abundance or density estimates are necessary for landbird management and conservation (Rosenstock et al. 2002, Thompson 2002, Jones et al. 2000). Fixed-radius point counts or point transects are among the most common avian counting techniques to estimate relative abundance of bird populations (Verner 1985, Hutto et al. 1986, Ralph and Scott 1981, Rosenstock et al. 2002, Thompson et al. 1998; review by Ralph et al. 1995). Fixed radius method assumes the number of individual birds counted (by sight or sound) represents a constant proportion or index of actual bird abundance (Williams et al. 2002a). Detection probabilities, and consequently proportion of birds counted, are assumed to be consistent among habitat, geographic location, and over time (Anderson 2001, Thompson 2002, Rosenstock et al. 2002, Renfrew and Ribic 2000).

However, validity of this "proportionality assumption" (Thompson 2002:18) is questionable (Barker and Sauer 1995, Diefenbach et al. 2003, Norvell et al. 2003); a count index is a function of actual abundance and detectability (Anderson et al. 2001, Pendleton 1995). Observer, weather, topography, habitat and bird species-specific attributes are known to affect detection probabilities (Bart and Schoultz 1984, Thompson et al. 1998, Bibby et al. 2000, Nichols et al. 2000, Rosenstock et al. 2002, Anderson 2001, Norvell et al. 2003). Despite considerable evidence that variation in detectibility frequently occurs, relative abundance indices are still widely used. In a recent review of papers using avian sampling methods in grassland habitats, Diefenbach et al. (2003) found > 90% of published studies did not test or adjust for differences in detection. Ignoring existence and variation in detection probability will lead to erroneous conclusions regarding density estimates, spatial distributions, population trends or habitat relationships (Pendleton, 1995, Rotella et al. 1999, Thompson 2002, Wilkinson et al. 2002, Rosenstock et al. 2002, Norvell et al. 2003).

Detection functions, derived from distance sampling, can be estimated with mathematical models developed by Burnham et al. (1980) to account for incomplete or unequal detection (Thompson et al. 1998). Essentially, the probability of detecting an individual or object decreases monotonically with increasing perpendicular distance from the observer (Burnham 1980, Buckland et al. 2001, Thomas et al. 2002, Williams et al. 2002b). Bird density estimated in this manner is considered unbiased, robust and has associated estimates of variance (Pyke and Recher 1985, Rotella et al. 1999, Buckland et al. 2001).

Avian detection probabilities remain mostly untested, especially in grassland ecosystems (Rotella et al. 1999, Norvell et al. 2003). With any method of population estimation, key assumptions should be thoroughly evaluated (Thompson 2002). Thus, my main objectives were to use distance-sampling methods (Buckland et al. 2001) to quantify species-, habitat-, and observer-specific detection probabilities, and to improve abundance estimates and bird-habitat patterns in main data chapters.

A.2 Methods

Intensive grassland bird identification training and distance estimation occurred in mid-May, 2001 and 2002, with the help of experienced birders prior to the field season (to reduce observer differences and increase distance estimation reliability). Roadside point count surveys were conducted following typical point count protocol. Distances to all visually detected birds from observers in 400-m radius plot in 3 minutes were estimated (with aid of a Bushnell Yardage Pro 500 ® laser range finder, accurate ± 1 m to 500 m) for upland-nesting shorebirds, grouse, gray partridge (*Perdix perdix*), black terns (*Childonias niger*), and all passerines except blackbirds and corvids. Preliminary observations confirmed detection probabilities for excluded species were generally constant and relatively high among all habitats out to 400 m. Distances estimated from aurally detected birds proved unreliable.

A.2.1 Analysis of distance data

Data were analyzed using program DISTANCE (version 3.5; Thomas et al. 1998) to generate detection functions (Rosenstock et al. 2002, Buckland et al. 2001, Buford et al. 1996). In general, detection probability will decrease with radial distance (Williams et al. 2002b). By modeling the detection function, the probability of observing an object in a define area, P_a, and effective detection radii (here after denoted as EDR) can be obtained. EDR is the radial distance for which the number of unseen animals located within the EDR equals the number of animals seen at distances greater than EDR (Thomas et al. 2002). EDR is commonly calculated to compare detection probabilities (Buckland et 2001). Detailed methods for model selection, truncation of observations at extreme distances, etc. are described by Buckland et al. (2001).

To determine whether proportions of detected individuals were comparable among duck density strata (Chapter 2), I evaluated global (i.e., distance estimates of all species in both years: 2001, n = 41 species; 2002, n = 40 species; Appendix B, Table B.1) stratum-specific detection probabilities. Detection functions (based on total distance estimates for all visually detected species) were calculated to determine whether general EDRs differed between years (2001, n = 41 species; 2002, n = 40 species; Appendix B, Table B.1).

Due to limited visual observations in all habitat classes, global EDRs were only compared between crop (i.e., point count stations encompassing > 40 ha of crop) and native habitats (i.e., point count with stations encompassing > 30 ha of native pasture and < 20 ha of crop) to determine if visual obstruction generally affects detection probability; I predicted that native vegetation would have higher visual obstruction compared to cultivated fields as crops tended to be sparse and short (< 0.5 m) during the survey season (personal observation).

To determine species-specific EDRs and evaluate detection abilities among observers and between years, detection functions of 5 visually abundant grassland bird species (i.e., > 80 visual distance estimates per year) were modeled. Finally, detection EDRs and P_as of nine “conspicuous” species (i.e., species with contrasting plumage colouration or pattern, large body size, or distinctive display behaviour) were contrasted with those of six “inconspicuous” species (i.e., species with cryptic colour or behaviour) to verify the extent of detection differences between the 2 groups (Appendix B, Table B.1). I predict visual EDR will be greatest for conspicuous birds.

A.2.2 Distance sampling assumptions

Unbiased estimation of animal density based on distance sampling rests on three assumptions. First, all objects at or near survey points should be detected (Bibby et al.

2000, Buckland et al. 2001, Rosenstock et al. 2002). Second, birds must be detected at initial location prior to movement in response to observer (Wilkinson et al. 2002) and should not be double-counted at a point. Third, radial distances from observer to bird should be free of measurement, rounding (i.e., heaping) or recording errors (Thompson et al. 1998, Anderson et al. 2001). Buckland et al. (2001) emphasize the importance of good field data; biases can be reduced with adequate distance training and use of digital range finders.

A.3 Results

A.3.1 Detection patterns

Visual observations accounted for < 10% of total birds recorded in 2001 and 2002 (n = 5,283 distance estimates). Species- and observer-specific detection patterns were evident. Most species evaluated (e.g., savannah sparrow, horned lark, lark bunting and bobolink) were inadequately detected near the center point, with deficit intervals ranging from 0-23 m among observer and between years. Detection surplus intervals were consistent among years, species and observers. Despite intensive distance estimation training and use of laser rangefinders, distance estimates were rounded to 10-, 20-, 50-, 75-, 100- and 150-m intervals, producing a “heaping” effect. However, in some cases, it was not clear whether these surpluses were due to rounding errors or bird behaviour (i.e., avoidance or attraction to observer) as surplus intervals tended to occur immediately beyond a deficit interval. To compensate for apparent assumption violations, I either grouped distance data in intervals that contained infrequent distance estimates (i.e., 0 - 20 m; Bibby et al. 2002, Buford et al. 1996, Thompson et al. 1998) or left-truncated distances within the deficit intervals to improve model fit (Buckland et al. 2001).

A.3.2 Detection probabilities

In general, birds were detected at greater distances in high duck stratum than in low or medium strata and general detection probability for all visually detected species was higher in 2002 than in 2001 (Tables A.1 and A.2). Birds could be detected further in native pastures than in cropland but detection probabilities did not differ between years (Table A.3). However, stratum-, year- and habitat-specific EDRs differed by < 5m. Detection functions differed among the 5 species analyzed but species-specific detection probabilities were consistent between years and among observers (Table A.4). As expected, observers were able to visually detect bobolinks (*Polichonyx oryzivorus*), western meadowlarks (*Sturnella neglecta*), and lark buntings (*Calamospiza melanocorys*) at greater distances (EDRs: 85 - 184 m) than savannah sparrows (*Passerculus sandwichensis*) or horned larks (EDRs: 44- 53 m). Probability of detecting these species at a given distance was also comparable between years and observers (Table A.4). Visually conspicuous species could be reliably detected about 42% (EDR ~ 76 m) further then visually inconspicuous species (EDR ~ 54 m). Probability (P_a) of detecting a conspicuous species within 90 m was 24% ($P_a \sim 0.45$) greater than for detecting inconspicuous species ($P_a \sim 0.36$; Table A.5). Consequently, stop-level priority species abundances were adjusted by a detection correction factor of 2.75 for "inconspicuous" species and by 2.25 for "conspicuous" species (Table 2.2). Original count data of Swainson's hawk and northern harrier were not adjusted.

A.4 Discussion

In general, proportions of visually detected birds were comparable among duck density strata. Similarly, I found detectibility was about equal in crop fields compared to native pastures (although probabilities specific to all habitat types could not be assessed). Therefore, individual species abundance estimates were not greatly affected by vegetation structure, habitat composition or topography in an open grassland system. However, as expected, our ability to reliably detect individuals varied widely among species. Individual species with distinct plumage colouration, or larger body size (e.g., western meadowlark, bobolink, lark bunting) were visually detected over twice as far

Table A.1. Estimated effective detection radii (EDR, in m) and detection probability (P_a) for all visually detected grassland bird species recorded in each duck density stratum, pooled between years and observers. Also shown are the numbers of visual distance estimates (n), the radial distance (*w*, in m) where visual observations were truncated and 95% confidence limits (lower and upper).

Stratum	n	*w*	EDR		P_a [a]	
Low	1395	180	48.2	(46.1 - 50.4)	0.072	(0.066 - 0.078)
Medium	1764	185	47.9	(46.1 - 49.7)	0.067	(0.062 - 0.072)
High	1656	175	56.9	(53.1 - 60.8)	0.106	(0.092 - 0.121)

[a] P_a is based on proportion of individuals detected within radial distance (*w*) of the point count center.

Table A.2. Estimated effective detection radii (EDR, in m) and detection probability (P_a) for all visually detected grassland bird species in 2001 and 2002. Also shown are the numbers of visual distance estimates (n), the radial distance (*w*, in m) where visual observations were truncated and 95% confidence limits (lower and upper).

Global[a]	n	*w*	EDR		P_a [b]	
2001	2621	177	55.9	(52.7 - 59.3)	0.110	(0.101 - 0.119)
2002	2133	177	62.3	(58.6 - 66.2)	0.100	(0.089 - 0.112)
2001/02 pooled	4754	177	58.6	(56.1 - 61.1)	0.124	(0.110 - 0.140)

[a] 2001 = 47 species visually detected; 2002 = 45 species visually detected; 2001/02 combined = 56 species visually detected.

[b] P_a is based on proportion of individuals detected within radial distance (*w*) of the point count center.

Table A.3. Estimated effective detection radii (EDR, in m) and detection probability (P_a) for all visually detected grassland bird species recorded cropland and native pasture in 2001 and 2002. Also shown are the numbers of visual distance estimates (n), the radial distance (*w*, in m) where visual observations were truncated and 95% confidence limits (lower and upper).

Habitat[a]	n	*w*	EDR		P_a [b]	
Cropland						
(2001)	1261	180	52.8	(45.0 - 61.9)	0.086	(0.063 - 0.118)
(2002)	950	180	58.7	(53.7 - 64.2)	0.160	(0.089 - 0.127)
(2001/02 pooled)	2111	180	55.4	(50.6 - 60.6)	0.095	(0.079 - 0.118)
Native pasture						
2001	147	160	70.7	(62.8 - 79.5)	0.195	(0.154 - 0.211)
2002	322	160	64.7	(57.4 - 72.9)	0.163	(0.154-0.247)
(2001/02 pooled)	469	160	67.6	(62.1 - 73.5)	0.178	(0.151 - 0.211)

[a] Cropland (2001/02) = 44 species visually detected; Native pasture (2001/02) = 32 species visually detected.

[b] P_a is based on proportion of individuals detected within radial distance (*w*) of the point count center.

Table A.4. Estimated effective detection radii (EDR, in m) and detection probability (P_a) for 6 grassland bird species for each year (2001 and 2002) and observer. Also shown are the numbers of visual distance estimates (n), the radial distance (*w*, in m) where visual observations were truncated and 95% confidence limits (lower and upper).

Species	Year	Observer	n	*w*	EDR		P_a [a]	
Western meadowlark	2001	JF	132	230	101.4	(77.4 -132.8)	0.184	(0.114 - 0.331)
		SS	193	230	117.0	(101.0 - 135.5)	0.259	(0.193 - 0.347)
		JF/SS pooled	322	230	113.5	(100.9 - 123.7)	0.244	(0.189 - 0.313)
	2002	HJ	56	282	99.3	(75.4 - 130.9)	0.158	(0.092 - 0.272)
		SS	252	282	117.3	(106.3 - 129.4)	0.220	(0.181 - 0.268)
		HJ/SS pooled	308	282	113.9	(103.6 - 125.3)	0.254	(0.172 - 0.251)
Horned lark	2001	JF	144	116	44.2	(38.1 - 51.2)	0.184	(0.108 - 0.195)
		SS	157	116	62.1	(56.3 - 68.5)	0.287	(0.237 - 0.349)
		JF/SS pooled	301	116	52.8	(48.7 - 57.2)	0.207	(0.176 - 0.243)
	2002	HJ	73	100	51.1	(44.3 - 58.9)	0.254	(0.192 - 0.336)
		SS	266	100	57.1	(52.7 - 61.8)	0.326	(0.278 - 0.382)
		HJ/SS pooled	339	100	55.7	(52.0 - 59.7)	0.309	(0.269 - 0.354)

Continued.

Table A.4. Continued.

Species	Year	Observer	n	*w*	EDR		P_a[a]	
Savannah sparrow	2001	JF	84	81	46.0	(38.1 - 55.7)	0.323	(0.221 - 0.471)
		SS	130	81	51.5	(46.6 - 56.9)	0.405	(0.331 - 0.494)
		JF/SS pooled	214	81	50.3	(46.3 - 54.7)	0.386	(0.326 - 0.456)
	2002	HJ	110	130	33.4	(15.0 - 74.5)	0.060	(0.015 - 0.282)
		SS	158	130	47.5	(40.7 - 55.4)	0.133	(0.098 - 0.181)
		HJ/SS pooled	268	130	44.4	(38.0 - 51.9)	0.117	(0.086 - 0.159)
Bobolink	2001	JF/SS pooled	80	300	183.8	(168.5 - 200.5)	0.375	(0.316 - 0.447)
Lark bunting	2002	HJ/SS pooled	92	180	85.2	(74.1 - 98.1)	0.224	(0.170 - 0.296)

[a] P_a is based on proportion of individuals detected within radial distance (*w*) of the point count center.

Table A.5. Estimated effective detection radii (EDR, in m) and detection probability (P_a) for conspicuous and inconspicuous grassland bird species in 2001 and 2002. Also shown are the numbers of visual distance estimates (n), the radial distance (*w*, in m) where visual observations were truncated and 95% confidence limits (lower and upper).

Group	n	*w*	EDR		P_a [c]		P_a (90 m) [d]	
Conspicuous species [a]								
2001	1131	203	73.3	(70.2 - 76.7)	0.131	(0.119 - 0.149)		
2002	858	203	90.8	(85.8 - 96.4)	0.200	(0.177 - 0.226)		
(2001/02 pooled)	1989	203	76.0	(71.2 - 81.1)	0.140	(0.123 - 0.160)	0.450	(0.415 - 0.488)
Inconspicuous species [b]								
2001	361	90	51.9	(48.2 - 55.9)	0.340	(0.293 - 0.395)		
2002	435	90	54.4	(51.1 - 58.0)	0.370	(0.330 - 0.424)		
(2001/02 pooled)	796	90	53.7	(49.2 - 55.9)	0.364	(0.309 - 0.429)	0.364	(0.309 - 0.429)

[a] Conspicuous species in both years: AMAV, BOBO, EAKI, KILL, LKBU, MAGO, WEKI, WEME and WILL.
[b] Inconspicuous species: BAIS, CCSP, GRSP, NSTS (2002 only), SAVS and VESP.
[c] P_a is based on proportion of individuals detected within radial distance (*w*) of the point count center.
[d] Maximum radial distance inconspicuous species were visually detected after data truncation.

(EDRs: 113-184 m) than smaller, more cryptic species (e.g., savannah sparrow, horned lark) were reliably observed (EDRs: 33-60 m). Further, a significantly greater proportion of the conspicuous species group was detected within the same given area compared to the inconspicuous group. These results were comparable with other recent grassland bird sampling studies that found detection probabilities varied widely among species and were generally low beyond 25 m (Rotella et al.1999, Diefenbach et al. 2003). Diefenbach et al. (2003) found grassland species-specific EDRs ranged from 39-84 m. Because of the considerable variation among species- and group-specific (i.e., conspicuous species versus inconspicuous species) detection probabilities, abundance estimates for key grassland groups (see Chapter 2 for group descriptions) may be unreliable. It is particularly critical that priority species abundance estimates are robust, as this group is comprised of species of greatest conservation concern. Therefore, each priority species was classed as conspicuous or inconspicuous and count data were adjusted with appropriate detection correction factors based on differences in detection between groups (Table 2.2). Abundance estimates of Swainson's hawk and northern harrier were not adjusted because I assume all individuals present within point count radii were detected during sampling period. These corrected counts were then used to determine best possible estimates for each main data chapter (i.e., stratum-specific abundance estimates, duck and other grassland bird abundance correlations, and ordination species scores).

Rotella et al. (1999) reported 90% of their data supported their prediction that all principal assumptions could be met with proper study design and distance estimation training in grassland habitat. In contrast, distance estimates obtained in this study were based on data that initially violated aspects of key sampling assumptions. First, detection deficits near point count centers along roads or trails coupled with detection surpluses of these species at distances > 20m suggest birds fled from approaching vehicles and tended to avoid roads and ditches or moved undetected away from observer. Similar to findings by Rotella et al. (1999), I found observer presence apparently repelled more elusive species such as savannah or clay-coloured sparrows. Also, bobolinks are known to avoid habitat edges (therefore were absent from ditches) and western meadowlarks tend to perch on nearby fence posts or electricity poles (Bollinger 1988, Rotenberry and

Knick 1995, Sutter et al. 2000). Second, our inability to record all birds at initial location, including those obviously flushed from count center, was probably inversely related to bird density within survey area (i.e., detection probability decreased as bird density increased; Tarvin et al. 1998, Bart and Schoultz 1984). Although detection deficits near center point can lead to under-estimated bird densities (Rotella et al. 1999), left-truncation of distance data did improve model fit. Third, evidence of heaping suggested distance estimation was not as accurate as expected. However, because distance data were collected as discrete distance estimates, data was grouped into intervals or truncated for more reliable density estimates (Buckland et al. 2001, Thompson et al. 1998, Buford et al. 1996). Nevertheless, these assumption violations were minor and were correctable (model fit improved); final detection functions were robust.

The critical limitation of my study was the inability to incorporate auditory observations to create complete detection functions. Based on my observations and field trials, I am very skeptical of studies claiming aural detections beyond 25 m were accurately estimated. Direction and distance of calling or singing bird relative to observer, wind speed and direction, topography, and species-specific song properties, and observer hearing ability will reduce accuracy and precision of acoustically detected distance estimates (Richards 1981, Stanley and Knopf 2002), regardless of amount of training or experience.

A.5 Conclusions and Recommendations

In summary, I was unable to quantify complete detection probabilities among species, observers or habitats because I could not estimate distances of auditory observations or collect sufficient visual distance estimates for all species across multiple habitats. Minor detection differences among grassland habitats or duck density strata had little consequence on abundance estimates. However, evidence of species-specific detection functions emphasized the need to correct for unequal detection probabilities among species in the priority group. Subsequent comparisons of abundance among duck strata, correlations between duck and other grassland bird species abundance and bird-habitat associations will be based on conservative, yet more reliable count data.

Though distance sampling is still under-used, use of distance sampling should be dependent upon study objectives, study species and quality of data. Distance sampling is recommended to reliable compare densities of several species or among multiple habitats to reliably infer area sensitivity, habitat preference, or population trends (Diefenbach et al. 2003). However, robust density estimates are not critical when modeling species occurrence (i.e., presence or absence) of rarer species (< 80 distance estimates may produce unreliable density estimates). Unlike count indices, all distance-sampling assumptions can be tested and detection patterns evaluated; and options exist to mediate moderate violations. Distance sampling can be an effective tool to illustrate detection differences among observers or highlight sampling deficiencies. For example, detection functions of less common species can indicate whether low species occurrence is a function of actual low density or poor detectibility. Yet, if detection functions are poorly modeled or major violations cannot be rectified, distance sampling should not be used.

Due to short comings in my study design, such as failure to incorporate auditory detections and difficulty in reliably estimating visual detection distances, I recommend several, practical modifications to distance sampling. First, limiting distance sampling to a small number key species (e.g., ≤ 6) will allow observers to concentrate on fewer birds and become more proficient at accurate distance estimates. Second, intensive and extensive distance estimation training for specific distances may improve estimation reliability. However, if individual distance estimates (by sight or sound) prove impractical, detects can be classified into pre-defined distance intervals (see Rotella et al. 1999, Manolis et al. 2002 but see Novella et al. 2003). Last, if detection probabilities are found constant out to a given radius among all habitats, researchers may choose to restrict count radius to obtain more reliable abundance estimates or evaluate habitat associations (Gawlik and Rocque 1998, Rotella et al. 1999, Madden et al. 2000).

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APPENDIX B: SUPPLEMENTAL TABLES AND FIGURES

Table B.1. Total number of visual detections for all species included in calculation of 2001 and 2002 global detection probability. Total number of visually detected species per year is included in parentheses.

Common Name	2001 (41)	2002 (40)	Common Name	2001 (41)	2002 (40)
American Avocet*	38	16	Le Conte's Sparrow	0	1
American Goldfinch	16	1	Least Flycatcher	2	1
American Robin	34	17	Lesser Yellowlegs	8	0
Baird's Sparrow†	13	10	Lark Bunting*	14	88
Baltimore Oriole	7	22	Loggerhead Shrike	7	5
Bank Swallow	0	6	Marbled Godwit*	52	39
Barn Swallow	83	82	Mourning Dove	101	60
Black-necked Stilt	2	0	Nelson's Sharp-tailed Sparrow†	0	6
Bobolink*	60	55	Savannah Sparrow†	115	131
Brown Thrasher	15	11	Sedge Wren	1	0
Chestnut-collared Longspur	21	49	Sora Rail	2	0
Clay-coloured Sparrow†	48	57	Song Sparrow	2	4
Cedar Waxwing	1	4	Sprague's Pipit	8	0
Cliff Swallow	18	2	Spotted Towhee	0	1
Common Snipe	8	10	Tree Swallow	9	1
Eastern Kingbird*	187	134	Upland Sandpiper	24	4
Grasshopper Sparrow†	2	7	Vesper Sparrow†	55	37
Horned Lark	168	197	Western Kingbird*	130	57
House Sparrow	38	37	Western Meadowlark*	194	89
House Wren	6	1	Willow Flycatcher	2	2
Killdeer*	76	46	Willet*	41	36
Lark Sparrow	2	0	Wilson's Phalarope	97	44
Long-billed Curlew	0	1	Yellow Warbler	4	1

† Inconspicuous species

* Conspicuous species

Table B.2. Species encountered along all routes surveyed in 2001 and 2002 (n = 93 routes). Listed are AOU codes, common name and scientific names, and total number of detections per species in each year.

AOU code	Common Name	Scientific Name	2001 (n = 107)	2002 (n = 106)
ALFL	Alder Flycatcher	*Empidonax alnorum*	0	1
AMAV	American Avocet	*Recurvirostra americana*	57	97
AMBI	American Bittern	*Botaurus lentiginous*	10	5
AMCO	American Coot	*Fulica americana*	855	376
AMCR	American Crow	*Corvus brachyrhynchos*	221	147
AMGO	American Goldfinch	*Carduelis tristis*	47	106
AMRO	American Robin	*Turdus migratorius*	107	83
AMWI	American Wigeon	*Anas americana*	102	139
AWPE	American White Pelican	*Pelecanus erythrorhynchos*	111	1
BAEA	Bald Eagle	*Haliaeetus leucocephalus*	0	1
BAIS	Baird's Sparrow	*Ammodramus bairdii*	451	530
BANS	Bank Swallow	*Riparia riparia*	0	13
BAOR	Balimore Oriole	*Icterus galbula*	33	7
BARS	Barn Swallow	*Hirundo rustica*	209	278
BBCU	Black-billed Cuckoo	*Coccyzus erythropthalmus*	0	2
BBMA	Black-billed Magpie	*Pica pica*	51	37
BCCH	Black-capped Chickadee	*Poecile atricapilla*	0	1
BCNH	Black-crowned Night Heron	*Nycticorax nycticorax*	0	4
BHCO	Brown-headed Cowbird	*Molothrus ater*	1835	2524
BLTE	Black Tern	*Chlidonias niger*	499	287
BNST	Black- necked Stilt	*Himantopus mexicanus*	2	2
BOBO	Bobolink	*Dolichonyx oryzivorus*	249	336
BRBL	Brewer's Blackbird	*Euphagus cyanocephalus*	362	343
BRTH	Brown Thrasher	*Toxostoma rufum*	72	51
BUFF	Bufflehead	*Bucephala albeola*	18	0
BWSP	Brewer's Sparrow	*Spizella breweri*	2	0
BWTE	Blue-winged Teal	*Anas discors*	747	780
CAGO	Canada Goose	*Branta canadensis*	568	94
CANV	Canvasback	*Aythya valisineria*	189	110
CCLO	Chestnut-collared longspur	*Calcarius ornatus*	268	419
CCSP	Clay-coloured Sparrow	*Spizella pallida*	778	648
CEDW	Cedar Waxwing	*Bombycilla cedrorum*	4	8
CHSP	Chipping Sparrow	*Spizella passerina*	4	9
CITE	Cinnamon Teal	*Anas cyanoptera*	1	0
CLSW	Cliff Swallow	*Hirundo pyrrhonota*	110	143
COGR	Common Grackle	*Quiscalus quiscula*	612	621
COME	Common Merganser	*Mergus merganser*	4	0
CONI	Common Nighthawk	*Chordeiles minor*	8	3
COSN	Common Snipe	*Gallinago gallinago*	138	135
COTE	Common Tern	*Sterna hirundo*	2	1
COYE	Common Yellowthroat	*Geothlypis trichas*	60	40

Continued.

Table B.2. Continued.

AOU code	Common Name	Scientific Name	2001 (n = 107)	2002 (n = 106)
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*	3	5
EAGR	Eared Grebe	*Podiceps nigricollis*	64	112
EAKI	Eastern Kingbird	*Tyrannus tyrannus*	605	540
FEHA	Ferruginous Hawk	*Buteo regalis*	2	0
FRGU	Franklin's Gull	*Larus pipixcan*	27	1
GADW	Gadwall	*Anas strepera*	476	670
GHOW	Great-horned Owl	*Bubo virginianus*	8	12
GRCA	Gray Catbird	*Dumetella carolinensis*	1	3
GRPA	Gray Partridge	*Perdix Perdix*	15	18
GRSP	Grasshopper Sparrow	*Ammodramus savannarum*	93	99
GRYE	Greater Yellowlegs	*Tringa melanoleuca*	0	22
GWTE	Green-winged Teal	*Anas crecca*	17	33
HOGR	Horned Grebe	*Podiceps auritus*	66	6
HOLA	Horned Lark	*Eremophila alpestris*	4011	4091
HOSP	House Sparrow	*Passer domesticus*	272	360
HOWR	House Wren	*Troglodytes aedon*	115	91
INBU	Indigo Bunting	*Passerina cyanea*	1	0
KILL	Killdeer	*Charadris vociferus*	336	322
LASP	Lark Sparrow	*Chondestes grammacus*	44	6
LBCU	Long-billed Curlew	*Numenius americanus*	0	13
LCSP	Le Conte's Sparrow	*Ammodramus leconteii*	34	9
LEFL	Least Flycatcher	*Empidonax minimus*	61	28
LESC	Lesser Scaup	*Aythya affinis*	378	254
LEYE	Lesser Yellowlegs	*Tringa flavipes*	10	70
LKBU	Lark Bunting	*Calamospiza melanocorys*	105	294
LOSH	Loggerhead Shrike	*Lanius ludovicianus*	9	10
MAGO	Marbled Godwit	*Limosa fedoa*	282	235
MALL	Mallard	*Anas platyrhynchos*	1132	1351
MAWR	Marsh Wren	*Cistothorus palustris*	22	19
MCLO	McCown's Longspur	*Calcarius mccownii*	4	0
MERL	Merlin	*Falco columbarius*	0	3
MOBL	Mountain Bluebird	*Sialia currucoides*	1	0
MODO	Mourning Dove	*Zenaida macroura*	629	496
NOFL	Northern Flicker	*Colaptes auratus*	0	3
NOHA	Northern Harrier	*Circus cyaneus*	53	30
NOPI	Northern Pintail	*Anas acuta*	316	321
NSHO	Northern Shoveler	*Anas clypeata*	512	323
NSTS	Nelson's Sharp-tailed Sparrow	*Ammodramus nelsoni*	24	48
OROR	Orchard Oriole	*Icterus spurius*	0	1
PBGR	Pie-billed Grebe	*Podilymbus podiceps*	95	17
PRFA	Prairie Falcon	*Falco mexicanus*	0	1
RBGU	Ring-billed Gull	*Larus delawarenis*	267	241

Continued.

Table B.2. Continued.

AOU code	Common Name	Scientific Name	2001 (n = 107)	2002 (n = 106)
REDH	Redhead	*Aythya americana*	269	106
REVI	Red-eyed Vireo	*Vireo olivaceus*	10	2
RGNP	Ring-necked Pheasant	*Phasianus colchicus*	43	57
RNGR	Red-necked Grebe	*Podiceps grisegena*	30	1
RODO	Rock Dove	*Columba livia*	10	28
ROWR	Rock Wren	*Salpinctes obsoletus*	1	0
RTHA	Red-tailed Hawk	*Buteo jamaicensis*	3	0
RUDU	Ruddy Duck	*Oxyura jamaicensis*	343	158
RUGR	Ruffed Grouse	*Bonasa umbellus*	0	1
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*	3532	2769
SACR	Sandhill Crane	*Grus canadensis*	0	1
SAPH	Say's Pheobe	*Sayornis saya*	2	2
SAVS	Savannah Sparrow	*Passerculus sandwichensis*	1856	1608
SEOW	Short-eared Owl	*Asio flammeus*	4	0
SEPL	Semipalmated Plover	*Charadrius semipalmatus*	2	0
SEWR	Sedge Wren	*Cistothorus platenis*	2	14
SORA	Sora Rail	*Porzana carolina*	187	61
SOSP	Song Sparrow	*Melospiza melodia*	24	54
SPPI	Sprague's Pipit	*Anthus spragueii*	152	191
SPTO	Spotted Towhee	*Pipilo maculatus*	1	1
STGR	Sharp-tailed Grouse	*Tympanuchus phasianellus*	39	27
STSA	Stilt Sandpiper	*Calidris himantopus*	0	1
SWHA	Swainson's Hawk	*Buteo swainsoni*	77	62
TKVU	Turkey Vulture	*Coragyps atratus*	2	0
TRES	Tree swallow	*Tachycineta bicolor*	15	20
UPSA	Upland Sandpiper	*Bartramia longicauda*	264	180
VEER	Veery	*Catharus fuscescens*	3	0
VESP	Vesper Sparrow	*Pooecetes gramineus*	912	628
VIRA	Virginia Rail	*Rallus limicola*	8	0
WAVI	Warbling Vireo	*Vireo gilvus*	49	17
WEKI	Western Kingbird	*Tyrannus verticalis*	316	317
WEME	Western Meadowlark	*Sturnella neglecta*	1864	1133
WIFL	Willow Flycatcher	*Empidonax traillii*	13	10
WILL	Willet	*Catoptrophorus semipalmatus*	223	212
WIPH	Wilson's Phalarope	*Phalaropus tricolor*	196	204
YBCH	Yellow-breasted Chat	*Icteria virens*	1	0
WTSP	White-throated Sparrow	*Zonotrichia albicollis*	0	1
YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	994	456
YTVI	Yellow-throated Vireo	*Vireo flavifrons*	1	0
YWAR	Yellow warbler	*Dendroica petechia*	85	67

Table B.3. Mean (± 1 SE) abundance of core duck, priority and common species encountered along 17 routes sampled in 2001 and 2002. The percentages of stops and routes where each species were detected are also given.

	2001						2002					
				Relative abundance						Relative abundance		
				Stratum						Stratum		
Common Name	Total detections	% Routes detected	% Stops detected	Low	Medium	High	Total detections	% Routes detected	% Stops detected	Low	Medium	High
Duck species	1,223			0.44 ± 0.23	2.49 ± 0.71	2.86 ± 1.21	1,411			0.20 ± 0.05	1.38 ± 0.76	5.07 ± 1.25
American Wigeon	47	23.5	2.2	0.00 ± 0.00	0.02 ± 0.02	0.18 ± 0.13	40	35.3	2.9	0.01 ± 0.01	0.04 ± 0.02	0.13 ± 0.07
Blue-winged Teal	196	76.5	8.6	0.08 ± 0.07	0.29 ± 0.17	0.54 ± 0.24	276	58.8	10.4	0.03 ± 0.03	0.17 ± 0.12	1.03 ± 0.41
Canvasback	99	29.4	1.9	0.00 ± 0.00	0.36 ± 0.27	0.14 ± 0.12	41	29.4	1.9	0.00 ± 0.00	0.01 ± 0.01	0.19 ± 0.10
Gadwall	159	70.6	8.0	0.03 ± 0.02	0.48 ± 0.20	0.30 ± 0.10	189	64.7	8.2	0.02 ± 0.01	0.14 ± 0.12	0.73 ± 0.14
Lesser Scaup	85	47.1	4.2	0.02 ± 0.01	0.13 ± 0.10	0.24 ± 0.14	88	41.2	3.0	0.00 ± 0.00	0.04 ± 0.03	0.36 ± 0.12
Mallard	279	100	13.4	0.13 ± 0.04	0.58 ± 0.10	0.61 ± 0.18	454	94.1	15.8	0.12 ± 0.04	0.60 ± 0.34	1.40 ± 0.35
Northern Pintail	63	64.7	4.0	0.09 ± 0.06	0.12 ± 0.04	0.09 ± 0.05	111	64.7	6.2	0.01 ± 0.01	0.03 ± 0.02	0.44 ± 0.12
Northern Shoveler	136	64.7	7.0	0.09 ± 0.06	0.22 ± 0.08	0.32 ± 0.22	140	58.8	6.1	0.03 ± 0.02	0.04 ± 0.02	0.57 ± 0.20
Redhead	73	35.3	3.0	0.00 ± 0.00	0.11 ± 0.07	0.23 ± 0.13	25	29.4	1.9	0.00 ± 0.00	0.03 ± 0.02	0.08 ± 0.06
Ruddy Duck	86	41.2	3.4	0.00 ± 0.00	0.18 ± 0.08	0.22 ± 0.13	47	47.1	1.9	0.00 ± 0.00	0.06 ± 0.04	0.14 ±0.05
Priority species	1,602			2.82 ± 1.07	2.60 ± 0.66	2.19 ± 0.44	2,593			3.75 ± 1.17	4.54 ± 1.62	4.00 ± 0.73
Baird's Sparrow	454	88.2	17.8	0.66 ± 0.20	0.75 ± 0.26	0.80 ± 0.23	638	88.2	25.0	0.95 ± 0.30	0.92 ± 0.31	1.18 ± 0.31
Bobolink	146	70.6	5.6	0.35 ± 0.22	0.16 ± 0.06	0.16 ± 0.06	270	64.7	11.0	0.75 ± 0.34	0.24 ± 0.11	0.19 ± 0.07
Chestnut-collared Longspur	308	64.7	10.6	0.75 ± 0.33	0.37 ± 0.17	0.31 ± 0.17	534	70.6	12.5	0.99 ± 0.39	1.03 ± 0.53	0.56 ± 0.27
Grasshopper Sparrow	107	58.8	5.1	0.15 ± 0.10	0.31 ± 0.11	0.07 ± 0.03	129	58.8	5.8	0.18 ± 0.12	0.40 ± 0.13	0.06 ± 0.03
Lark Bunting	106	52.9	4.5	0.18 ± 0.08	0.28 ± 0.26	0.08 ± 0.04	326	70.6	9.1	0.25 ± 0.13	1.15 ± 0.58	0.26 ± 0.14
Le Conte's Sparrow	30	35.3	1.4	0.02 ± 0.02	0.04 ± 0.03	0.08 ± 0.04	14	29	0.8	0.03 ± 0.02	0.00 ± 0.00	0.02 ± 0.01
Marbled Godwit	146	82.4	7.4	0.23 ± 0.09	0.30 ± 0.13	0.14 ± 0.07	140	82.4	6.6	0.19 ± 0.09	0.35 ± 0.15	0.13 ± 0.05
Nelson's Sharp-tailed Sparrow	19	23.5	1.1	0.02 ± 0.02	0.07 ± 0.07	0.02 ± 0.01	52	58.8	2.6	0.03 ± 0.03	0.08 ± 0.03	0.14 ± 0.05
Northern Harrier	11	35.3	1.8	0.02 ± 0.01	0.02 ± 0.02	0.01 ± 0.01	12	47.1	1.8	0.03 ± 0.01	0.02 ± 0.01	0.01 ± 0.01

Continued.

Table B.3 Continued.

Common Name	2001 Total detections	2001 % Routes detected	2001 % Stops detected	2001 Relative abundance Stratum Low	2001 Relative abundance Stratum Medium	2001 Relative abundance Stratum High	2002 Total detections	2002 % Routes detected	2002 % Stops detected	2002 Relative abundance Stratum Low	2002 Relative abundance Stratum Medium	2002 Relative abundance Stratum High
Priority species												
Sprague's Pipit	127	58.8	5.6	0.30 ± 0.09	0.14 ± 0.09	0.16 ± 0.10	195	76.5	8.8	0.30 ± 0.14	0.22 ± 0.11	0.41 ± 0.17
Swainson's Hawk	19	70.6	2.9	0.02 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	36	64.7	4.6	0.05 ± 0.03	0.06 ± 0.03	0.06 ± 0.02
Wilson's Phalarope	128	58.8	3.4	0.13 ± 0.12	0.13 ± 0.06	0.31 ± 0.12	248	47.1	4.0	0.02 ± 0.02	0.05 ± 0.03	0.99 ± 0.36
Common species	6,215			7.63 ± 1.04	11.45 ± 0.89	10.47 ± 1.33	7,779			10.23 ± 1.29	14.08 ± 0.93	12.94 ± 0.88
American Avocet	10	23.5	1.0	0.00 ± 0.00	0.02 ± 0.02	0.03 ± 0.02	64	29.4	1.8	0.00 ± 0.00	0.22 ± 0.22	0.08 ± 0.05
American Coot	179	58.8	9.9	0.02 ± 0.02	0.25 ± 0.12	0.55 ± 0.18	86	47.1	3.5	0.01 ± 0.01	0.08 ± 0.05	0.30 ± 0.17
American Crow	72	82.4	9.3	0.13 ± 0.05	0.14 ± 0.05	0.08 ± 0.04	50	88.2	5.6	0.11 ± 0.03	0.07 ± 0.03	0.06 ± 0.01
American Goldfinch	13	23.5	0.8	0.03 ± 0.03	0.02 ± 0.01	0.00 ± 0.00	39	64.7	3.4	0.03 ± 0.01	0.04 ± 0.01	0.13 ± 0.08
American Robin	39	70.6	4.6	0.04 ± 0.02	0.06 ± 0.02	0.08 ± 0.03	37	82.4	5.1	0.07 ± 0.03	0.05 ± 0.01	0.07 ± 0.02
Baltimore Oriole	17	41.2	2.7	0.02 ± 0.01	0.03 ± 0.01	0.04 ± 0.03	3	12	0.5	0.01 ± 0.01	0.01 ± 0.01	0.00 ± 0.00
Barn Swallow	82	76.5	5.6	0.13 ± 0.04	0.15 ± 0.04	0.11 ± 0.06	113	88.2	7.2	0.14 ± 0.06	0.17 ± 0.11	0.21 ± 0.06
Black-billed Magpie	14	35.3	1.6	0.05 ± 0.02	0.02 ± 0.01	0.00 ± 0.00	14	29.4	1.3	0.07 ± 0.03	0.01 ± 0.01	0.00 ± 0.00
Brown-headed Cowbird	408	100	32.6	0.43 ± 0.18	0.85 ± 0.10	0.66 ± 0.25	1,018	100	52.8	1.24 ± 0.25	1.91 ± 0.41	1.63 ± 0.17
Brewer's Blackbird	127	94.1	7.7	0.17 ± 0.06	0.19 ± 0.06	0.26 ± 0.10	143	88.2	8.2	0.17 ± 0.06	0.20 ± 0.06	0.33 ± 0.08
Brown Thrasher	28	64.7	3.7	0.03 ± 0.01	0.09 ± 0.04	0.01 ± 0.01	22	82.4	3.4	0.02 ± 0.01	0.04 ± 0.01	0.04 ± 0.01
Canada Goose	117	64.7	6.4	0.11 ± 0.09	0.29 ± 0.12	0.15 ± 0.08	9	17.6	0.6	0.00 ± 0.00	0.01 ± 0.01	0.04 ± 0.03
Clay-coloured Sparrow	248	100	26.2	0.31 ± 0.07	0.49 ± 0.09	0.41 ± 0.05	308	94.1	26.6	0.55 ± 0.23	0.50 ± 0.15	0.43 ± 0.13
Common Grackle	112	76.5	7.2	0.14 ± 0.04	0.22 ± 0.13	0.17 ± 0.10	297	100	16.8	0.35 ± 0.15	0.41 ± 0.06	0.65 ± 0.18
Common Snipe	41	70.6	6.4	0.03 ± 0.02	0.06 ± 0.02	0.11 ± 0.03	50	82.4	7.2	0.04 ± 0.02	0.08 ± 0.03	0.11 ± 0.02
Common Yellowthroat	18	41.2	2.9	0.01 ± 0.01	0.04 ± 0.02	0.03 ± 0.02	8	35.3	1.1	0.01 ± 0.01	0.02 ± 0.01	0.01 ± 0.01
Eastern Kingbird	160	100	18.6	0.14 ± 0.03	0.37 ± 0.05	0.27 ± 0.05	236	100	22.6	0.25 ± 0.06	0.40 ± 0.10	0.47 ± 0.06
Horned Grebe	32	17.6	1.4	0.00 ± 0.00	0.01 ± 0.01	0.13 ± 0.12	0	0	0	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Continued.

Table B.3 Continued.

Common Name	2001						2002					
				Relative abundance						Relative abundance		
				Stratum						Stratum		
	Total detections	% Routes detected	% Stops detected	Low	Medium	High	Total detections	% Routes detected	% Stops detected	Low	Medium	High
Common species												
Horned Lark	1,165	100	77.3	1.91 ± 0.23	2.07 ± 0.31	1.59 ± 0.24	1,752	100.0	77.3	3.34 ± 0.23	2.66 ± 0.47	2.39 ± 0.22
House Sparrow	62	70.6	4.5	0.04 ± 0.03	0.16 ± 0.06	0.11 ± 0.03	131	94.1	7.0	0.18 ± 0.05	0.18 ± 0.13	0.25 ± 0.04
House Wren	40	64.7	5.4	0.04 ± 0.02	0.06 ± 0.03	0.09 ± 0.04	30	64.7	3.5	0.04 ± 0.02	0.06 ± 0.02	0.03 ± 0.02
Killdeer	108	88.2	15.2	0.08 ± 0.04	0.21 ± 0.04	0.23 ± 0.04	102	94.1	14.2	0.11 ± 0.03	0.13 ± 0.04	0.24 ± 0.05
Lark Sparrow	6	29.4	1.0	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	5	24	0.8	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.01
Least Flycatcher	20	64.7	3.2	0.01 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	12	35.3	1.6	0.01 ± 0.01	0.01 ± 0.01	0.03± 0.02
Marsh Wren	5	11.8	0.5	0.00 ± 0.00	0.02 ± 0.02	0.01 ± 0.01	4	17.6	0.6	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.01
Mourning Dove	191	100	22.1	0.18 ± 0.08	0.43 ± 0.06	0.31 ± 0.07	250	100.0	23.4	0.31 ± 0.12	0.60 ± 0.12	0.27 ± 0.06
Pie-billed Grebe	45	47.1	3.2	0.00 ± 0.00	0.12 ± 0.12	0.10 ± 0.03	2	12	0.3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Red-winged Blackbird	930	100	53.4	0.87 ± 0.31	1.58 ± 0.28	1.92 ± 0.24	1,065	100	48.2	1.33 ± 0.27	1.63 ± 0.40	2.02 ± 0.20
Savannah Sparrow	543	100	50.6	1.09 ± 0.24	0.80 ± 0.14	0.63 ± 0.07	666	100	56.3	1.59 ± 0.26	0.84 ± 0.17	0.77 ± 0.06
Sedge Wren	1	6	0.2	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	2	11.8	0.3	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
Sora Rail	65	76.5	9.3	0.01 ± 0.01	0.12 ± 0.02	0.17 ± 0.06	20	41.2	3.2	0.00 ± 0.00	0.03 ± 0.02	0.06 ± 0.02
Song Sparrow	10	29.4	1.1	0.00 ± 0.00	0.01 ± 0.01	0.04 ± 0.02	9	41.2	1.4	0.00 ± 0.00	0.01 ± 0.01	0.03 ± 0.01
Tree swallow	1	6	0.2	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	3	17.6	0.5	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.01
Upland Sandpiper	81	76.5	12.2	0.13 ± 0.04	0.14 ± 0.06	0.11 ± 0.05	79	94.1	9.0	0.15 ± 0.05	0.15 ± 0.05	0.07 ± 0.04
Vesper Sparrow	292	100	34.6	0.45 ± 0.20	0.59 ± 0.09	0.43 ± 0.08	260	94.1	29.4	0.45 ± 0.27	0.51 ± 0.06	0.35 ± 0.07
Warbling Vireo	20	41.2	2.6	0.02 ± 0.01	0.03 ± 0.02	0.05 ± 0.04	8	17.6	1.1	0.00 ± 0.00	0.02 ± 0.02	0.02 ± 0.02
Western Kingbird	75	94.1	6.2	0.08 ± 0.02	0.16 ± 0.07	0.13 ± 0.02	143	100	11.7	0.17 ± 0.11	0.27 ± 0.09	0.27 ± 0.06
Western Meadowlark	532	100	63.5	0.79 ± 0.08	1.07 ± 0.19	0.70 ± 0.13	441	100	53.0	0.67 ± 0.12	0.80 ± 0.08	0.66 ± 0.09
Willet	83	94.1	12.2	0.07 ± 0.03	0.16 ± 0.04	0.16 ± 0.04	84	88.2	10.9	0.04 ± 0.02	0.15 ± 0.03	0.20 ± 0.03
Yellow-headed Blackbird	197	82.4	13.0	0.04 ± 0.02	0.35 ± 0.13	0.54 ± 0.19	184	76.5	12.0	0.04 ± 0.03	0.11 ± 0.06	0.67 ± 0.13
Yellow warbler	26	70.6	3.5	0.04 ± 0.01	0.02 ± 0.01	0.07 ± 0.03	30	41.2	3.8	0.02 ± 0.02	0.07 ± 0.06	0.05 ± 0.02

Table B.4. Core species encountered routes unique to 2001 (n = 41 routes; 61 species) and 2002 (n = 33 routes; 57 species). Mean (± 1 SE) abundance of each species in all 3 duck density strata is listed. The percentage (%) of stops and routes where each species was detected is also given.

	2001						2002					
				Relative abundance						Relative abundance		
				Stratum						Stratum		
Common Name	Total detections	% Routes detected	% Stops detected	Low	Medium	High	Total detections	% Routes detected	% Stops detected	Low	Medium	High
Duck species	3,793			0.40 ± 0.12	2.43 ± 0.52	4.13 ± 0.75	3,212			0.39 ± 0.10	1.23 ± 0.29	5.97 ± 1.30
American Wigeon	86	39.0	2.2	0.01 ± 0.00	0.01 ± 0.01	0.15 ± 0.06	118	39.4	3.4	0.00 ± 0.00	0.06 ± 0.02	0.22 ± 0.06
Blue-winged Teal	671	85.4	12.0	0.10 ± 0.04	0.39 ± 0.12	0.72 ± 0.19	601	60.6	8.6	0.01 ± 0.01	0.17 ± 0.08	1.23 ± 0.37
Canvasback	180	41.5	1.9	0.00 ± 0.00	0.18 ± 0.09	0.13 ± 0.05	55	27.3	1.2	0.00 ± 0.00	0.03 ± 0.03	0.11 ± 0.04
Gadwall	401	73.2	8.3	0.03 ± 0.01	0.24 ± 0.08	0.47 ± 0.13	523	63.6	9.5	0.02 ± 0.01	0.23 ± 0.09	0.98 ± 0.23
Lesser Scaup	344	53.7	4.7	0.02 ± 0.01	0.21 ± 0.14	0.43 ± 0.14	185	33.3	2.7	0.00 ± 0.00	0.00 ± 0.00	0.44 ± 0.13
Mallard	925	97.6	16.8	0.17 ± 0.03	0.59 ± 0.14	0.96 ± 0.18	1,049	90.9	17.1	0.30 ± 0.08	0.00 ± 0.00	1.73 ± 0.41
Northern Pintail	246	63.4	6.0	0.04 ± 0.03	0.19 ± 0.08	0.20 ± 0.06	238	72.7	5.9	0.05 ± 0.03	0.16 ± 0.04	0.35 ± 0.08
Northern Shoveler	407	73.2	9.2	0.04 ± 0.03	0.28 ± 0.08	0.40 ± 0.10	240	57.6	5.3	0.01 ± 0.01	0.12 ± 0.05	0.44 ± 0.12
Redhead	234	46.3	2.8	0.00 ± 0.00	0.16 ± 0.07	0.27 ± 0.08	86	21.2	1.4	0.00 ± 0.00	0.00 ± 0.00	0.20 ± 0.08
Ruddy Duck	299	46.3	4.5	0.00 ± 0.00	0.16 ± 0.07	0.39 ± 0.11	117	30.3	2.2	0.00 ± 0.00	0.01 ± 0.01	0.26 ± 0.08
Priority species	3,777			2.59 ± 0.65	2.11 ± 0.36	2.69 ± 0.43	4,609			4.04 ± 0.98	3.34 ± 0.59	3.35 ± 0.57
Baird's Sparrow	919	78.0	14.6	0.49 ± 0.14	0.52 ± 0.14	0.85 ± 0.22	1161	97.0	19.4	0.98 ± 0.31	0.88 ± 0.24	0.83 ± 0.20
Bobolink	495	68.3	7.5	0.71 ± 0.41	0.18 ± 0.05	0.21 ± 0.12	630	72.7	10.9	0.85 ± 0.23	0.38 ± 0.13	0.20 ± 0.09
Chestnut-collared Longspur	544	61.0	7.2	0.44 ± 0.18	0.39 ± 0.12	0.21 ± 0.09	897	81.8	10.3	1.00 ± 0.29	0.73 ± 0.25	0.37 ± 0.12
Grasshopper Sparrow	190	53.7	3.9	0.14 ± 0.07	0.10 ± 0.04	0.11 ± 0.04	173	57.6	3.7	0.14 ± 0.05	0.09 ± 0.03	0.17 ± 0.06
Lark Bunting	164	29.3	2.4	0.08 ± 0.04	0.17 ± 0.10	0.05 ± 0.03	412	66.7	6.1	0.27 ± 0.08	0.32 ± 0.13	0.41 ± 0.11
Le Conte's Sparrow*	72	36.6	1.4	0.04 ± 0.02	0.07 ± 0.03	0.03 ± 0.01						
Marbled Godwit	513	70.7	7.6	0.12 ± 0.05	0.27 ± 0.07	0.52 ± 0.24	461	81.8	7.4	0.31 ± 0.12	0.31 ± 0.10	0.43 ± 0.30
Nelson's Sharp-tailed Sparrow	60	31.7	1.4	0.03 ± 0.02	0.06 ± 0.02	0.04 ± 0.02	96	57.6	2.5	0.04 ± 0.02	0.05 ± 0.02	0.14 ± 0.03
Northern Harrier	50	58.5	3.0	0.03 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	27	51.5	2.0	0.02 ± 0.01	0.01 ± 0.01	0.03 ± 0.01

Continued.

Table B.4. Continued.

Common Name	2001						2002					
				Relative abundance						Relative abundance		
				Stratum						Stratum		
	Total detections	% Routes detected	% Stops detected	Low	Medium	High	Total detections	% Routes detected	% Stops detected	Low	Medium	High
Priority species												
Sprague's Pipit	308	46.3	6.1	0.21 ± 0.09	0.12 ± 0.05	0.25 ± 0.08	459	72.7	9.7	0.37 ± 0.16	0.31 ± 0.15	0.36 ± 0.18
Swainson's Hawk	68	75.6	3.9	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	34	51.5	2.3	0.02 ± 0.01	0.02 ± 0.01	0.05 ± 0.01
Wilson's Phalarope	394	58.5	3.2	0.25 ± 0.13	0.14 ± 0.04	0.35 ± 0.10	259	57.6	2.8	0.04 ± 0.03	0.26 ± 0.09	0.34 ± 0.08
Common species	9,026			9.26 ± 0.92	13.52 ± 0.84	13.31 ± 0.91	8,089			9.52 ± 0.76	12.42 ± 0.82	13.64 ± 0.77
American Avocet	50	36.6	1.3	0.01 ± 0.01	0.04 ± 0.01	0.04 ± 0.02	38	27.3	1.2	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.03
American Coot	768	80.5	17.8	0.02 ± 0.01	0.50 ± 0.20	0.83 ± 0.12	303	48.5	4.3	0.01 ± 0.01	0.04 ± 0.02	0.66 ± 0.24
American Crow	171	78.0	9.4	0.12 ± 0.03	0.12 ± 0.03	0.10 ± 0.03	137	90.9	8.4	0.08 ± 0.02	0.10 ± 0.03	0.14 ± 0.03
American Goldfinch	45	39.0	1.5	0.04 ± 0.02	0.01 ± 0.01	0.04 ± 0.02	89	75.8	4.6	0.06 ± 0.01	0.06 ± 0.02	0.07 ± 0.02
American Robin	86	68.3	4.5	0.05 ± 0.02	0.05 ± 0.01	0.05 ± 0.02	59	75.8	4.2	0.04 ± 0.01	0.06 ± 0.02	0.04 ± 0.01
Baltimore Oriole*	20	31.7	1.3	0.02 ± 0.01	0.01 ± 0.00	0.02 ± 0.01						
Barn Swallow	152	70.7	5.1	0.11 ± 0.02	0.11 ± 0.02	0.07 ± 0.02	228	90.9	7.9	0.18 ± 0.04	0.14 ± 0.04	0.22 ± 0.06
Black-billed Magpie	46	36.6	1.5	0.07 ± 0.03	0.02 ± 0.01	0.01 ± 0.01	27	45.5	1.6	0.03 ± 0.01	0.03 ± 0.01	0.01 ± 0.00
Brown-headed Cowbird	1,614	100	44.2	0.61 ± 0.14	1.24 ± 0.17	1.20 ± 0.15	1,992	100	48.9	1.03 ± 0.14	1.93 ± 0.22	1.77 ± 0.23
Brewer's Blackbird	246	85.4	6.9	0.10 ± 0.03	0.17 ± 0.04	0.23 ± 0.05	281	93.9	9.1	0.22 ± 0.04	0.23 ± 0.05	0.23 ± 0.04
Brown Thrasher	53	61.0	3.1	0.03 ± 0.01	0.04 ± 0.01	0.02 ± 0.01	43	75.8	3.1	0.02 ± 0.00	0.05 ± 0.01	0.04 ± 0.01
Canada Goose	504	53.7	5.5	0.04 ± 0.03	0.55 ± 0.20	0.28 ± 0.20	124	33.3	1.2	0.04 ± 0.03	0.15 ± 0.09	0.11 ± 0.06
Clay-coloured Sparrow	641	97.6	27.9	0.40 ± 0.09	0.37 ± 0.07	0.50 ± 0.05	470	93.9	21.4	0.29 ± 0.08	0.30 ± 0.09	0.51 ± 0.10
Common Grackle	558	82.9	10.5	0.23 ± 0.08	0.42 ± 0.11	0.35 ± 0.10	464	97.0	13.8	0.25 ± 0.07	0.33 ± 0.10	0.52 ± 0.13
Common Snipe	114	63.4	7.2	0.02 ± 0.02	0.07 ± 0.01	0.11 ± 0.02	113	75.8	7.9	0.04 ± 0.01	0.12 ± 0.03	0.11 ± 0.02
Common Yellowthroat	42	53.7	2.6	0.02 ± 0.01	0.02 ± 0.01	0.05 ± 0.01	36	48.5	2.3	0.01 ± 0.00	0.02 ± 0.01	0.05 ± 0.02
Eastern Kingbird	508	100	19.5	0.23± 0.04	0.35 ± 0.04	0.39 ± 0.05	404	100	19.5	0.23 ± 0.03	0.31 ± 0.07	0.41 ± 0.05
Horned Grebe*	64	26.8	1.4	0.00 ± 0.00	0.02 ± 0.02	0.09 ± 0.05						
Horned Lark	3,344	100	74.7	2.24 ± 0.31	2.53 ± 0.24	1.71 ± 0.19	3,281	100	73.3	2.85 ± 0.35	2.84 ± 0.14	2.06 ± 0.17

Continued.

Table B.4. Continued.

	2001						2002					
				Relative abundance						Relative abundance		
				Stratum						Stratum		
Common Name	Total detections	% Routes detected	% Stops detected	Low	Medium	High	Total detections	% Routes detected	% Stops detected	Low	Medium	High
Common species												
House Sparrow	196	80.5	5.3	0.15 ± 0.06	0.16 ± 0.03	0.06 ± 0.02	279	87.9	6.9	0.17 ± 0.05	0.31 ± 0.12	0.19 ± 0.04
House Wren	89	68.3	4.2	0.06 ± 0.02	0.05 ± 0.02	0.06 ± 0.01	71	69.7	4.2	0.04 ± 0.01	0.07 ± 0.02	0.06 ± 0.01
Killdeer	278	97.6	15.2	0.12 ± 0.03	0.19 ± 0.03	0.20 ± 0.03	255	97.0	15.8	0.12 ± 0.02	0.19 ± 0.03	0.30 ± 0.05
Lark Sparrow*	40	24.4	1.4	0.07 ± 0.06	0.01 ± 0.01	0.01 ± 0.00						
Least Flycatcher	52	65.9	3.3	0.05 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	22	39.4	1.6	0.01 ± 0.00	0.03 ± 0.01	0.02 ± 0.01
Marsh Wren*	22	29.3	1.2	0.00 ± 0.00	0.01 ± 0.01	0.02 ± 0.01						
Mourning Dove	516	95.1	24.5	0.31 ± 0.06	0.33 ± 0.05	0.3 4 ± 0.06	331	97.0	15.3	0.19 ± 0.03	0.32 ± 0.09	0.28 ± 0.05
Pie-billed Grebe*	80	41.5	2.9	0.00 ± 0.00	0.06 ± 0.04	0.08 ± 0.03						
Red-winged Blackbird	3,107	100	57.5	0.99 ± 0.18	2.38 ± 0.26	2.56 ± 0.27	2,174	100	44.9	1.14 ± 0.25	1.87 ± 0.24	2.20 ± 0.17
Savannah Sparrow	1,488	100	55.4	1.28 ± 0.18	0.93 ± 0.10	0.78 ± 0.06	1,308	100	56.0	1.22 ± 0.19	0.98 ± 0.12	0.82 ± 0.06
Sedge Wren†							13	24.2	0.7	0.02 ± 0.01	0.00 ± 0.00	0.01 ± 0.01
Sora Rail	154	73.2	9.1	0.00 ± 0.00	0.12 ± 0.02	0.15 ± 0.02	45	57.6	3.3	0.01 ± 0.00	0.03 ± 0.01	0.07 ± 0.02
Song Sparrow	20	26.8	1.2	0.01 ± 0.01	0.00 ± 0.00	0.02 ± 0.01	52	60.6	3.8	0.02 ± 0.01	0.03 ± 0.01	0.07 ± 0.02
Tree swallow†							19	30.3	0.8	0.01 ± 0.00	0.02 ± 0.02	0.01 ± 0.01
Upland Sandpiper	233	87.8	14.3	0.10 ± 0.03	0.19 ± 0.05	0.14 ± 0.03	123	90.9	7.4	0.09 ± 0.02	0.11 ± 0.05	0.09 ± 0.02
Vesper Sparrow	731	92.7	33.7	0.41 ± 0.14	0.41 ± 0.05	0.60 ± 0.08	477	93.9	27.2	0.23 ± 0.10	0.37 ± 0.10	0.52± 0.05
Warbling Vireo	37	48.8	2.2	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	13	30.3	0.9	0.01 ± 0.00	0.00 ± 0.00	0.02 ± 0.01
Western Kingbird	281	97.6	10.0	0.14 ± 0.03	0.23 ± 0.05	0.17 ± 0.03	224	93.9	9.2	0.09 ± 0.02	0.18 ± 0.04	0.26 ± 0.04
Western Meadowlark	1,521	100	68.5	1.04 ± 0.14	1.08 ± 0.08	0.82 ± 0.08	926	100	53.7	0.70 ± 0.08	0.75 ± 0.09	0.72 ± 0.07
Willet	189	82.9	11.1	0.07 ± 0.02	0.14 ± 0.02	0.14 ± 0.03	167	87.9	9.7	0.07 ± 0.03	0.14 ± 0.03	0.18 ± 0.04
Yellow-headed Blackbird	849	92.7	18.3	0.03 ± 0.01	0.55 ± 0.09	0.95 ± 0.19	393	69.7	9.6	0.02 ± 0.01	0.24 ± 0.10	0.68 ± 0.13
Yellow warbler	64	61.0	3.7	0.04 ± 0.02	0.02 ± 0.01	0.06 ± 0.02	56	57.6	3.4	0.01 ± 0.00	0.07 ± 0.04	0.05 ± 0.01

* Core species unique to 2001 data set

† Core species unique to 2002 data set

Table B.5. Pearson's correlation coefficients (r) for 10 habitat classes and 9 landscape structure matrices with 3 DCA functions for 63 core species based on a randomly selected, 33% subset of stop points (n = 888). Also shown is the significance value (*P*) of each correlation and % variance explained by the first 3 DCA axes.

	DCA 1		DCA 2		DCA 3	
	r	P	r	P	r	P
Landcover classes						
Cropland (ha)	-0.030	0.378	-0.238	< 0.001	-0.594	< 0.001
Forage (ha)	0.066	0.051	0.070	0.036	0.128	< 0.001
Native grasslands (ha)	-0.153	< 0.001	0.249	< 0.001	0.537	< 0.001
Tame pasture (ha)	0.093	0.005	0.035	0.300	0.111	0.001
Shrub (ha)	0.063	0.059	0.090	0.007	0.293	< 0.001
Trees (ha)	0.125	0.000	0.110	0.001	0.141	< 0.001
Wetlands (ha)	0.279	< 0.001	-0.215	< 0.001	0.290	< 0.001
Open waterbodies (ha)	0.227	< 0.001	-0.137	< 0.001	0.086	0.011
Otherlands (ha)	0.304	< 0.001	0.338	< 0.001	-0.068	0.042
Mud/ sand/ saline (ha)	0.064	0.056	-0.081	0.016	0.073	0.029
Landscape structure						
Heterogeneity index	0.387	< 0.001	0.130	< 0.001	0.410	< 0.001
Number of patches	0.222	< 0.001	0.023	0.494	0.369	< 0.001
Mean patch size (ha)	-0.456	< 0.001	-0.047	0.157	-0.383	< 0.001
Mean core area (ha)	-0.439	< 0.001	-0.066	0.049	-0.464	< 0.001
Total edge (m)	0.321	< 0.001	0.026	0.440	0.430	< 0.001
Number of native grasslands patches	0.094	0.005	0.074	0.027	0.247	< 0.001
Mean native grassland (ha) patch size	-0.193	< 0.001	0.215	< 0.001	0.423	< 0.001
Mean native grassland core area (ha)	-0.184	< 0.001	0.185	< 0.001	0.305	< 0.001
% Variance explained	23.4		13.7		9.7	

Table B.6. Pearson's correlation coefficients (r) for 10 habitat classes and 9 landscape structure matrices with 3 DCA functions for 10 duck species based all stop points (n = 825) where ≥ 1 duck species was present. Also shown is the significance value (*P*) of each correlation and % variance explained by the first 3 DCA axes.

	DCA 1		DCA 2		DCA 3	
	r	P	r	P	r	P
Landcover classes						
Cropland (ha)	-0.121	< 0.001	-0.027	0.431	0.026	0.448
Forage (ha)	0.097	0.005	-0.003	0.926	0.019	0.571
Native grasslands (ha)	-0.004	0.919	0.034	0.326	-0.032	0.350
Tame pasture (ha)	0.024	0.492	0.027	0.434	0.070	0.042
Shrub (ha)	0.023	0.502	-0.015	0.664	-0.014	0.672
Trees (ha)	-0.029	0.405	-0.052	0.132	-0.025	0.458
Wetlands (ha)	0.183	< 0.001	0.016	0.637	-0.043	0.208
Open waterbodies (ha)	0.209	< 0.001	-0.014	0.685	-0.015	0.661
Otherlands (ha)	0.015	0.669	0.024	0.480	-0.063	0.066
Mud/ sand/ saline (ha)	0.003	0.929	0.004	0.896	-0.019	0.566
Landscape structure						
Heterogeneity index	0.228	< 0.001	0.015	0.648	-0.026	0.454
Number of patches	0.109	0.001	-0.032	0.350	0.000	0.991
Mean patch size (ha)	-0.213	< 0.001	0.003	0.921	0.018	0.593
Mean core area (ha)	-0.250	< 0.001	-0.039	0.260	0.065	0.061
Total edge (m)	0.175	< 0.001	-0.009	0.796	-0.037	0.285
Number of native grasslands patches	0.021	0.555	0.009	0.794	-0.010	0.768
Mean native grassland (ha) patch size	-0.043	0.218	0.055	0.111	-0.009	0.790
Mean native grassland core area (ha)	-0.094	0.006	0.005	0.874	-0.027	0.430
% Variance explained	29.6		28.7		10.4	

Table B.7. Pearson's correlation coefficients (r) for 10 habitat classes and 9 landscape-structure matrices with 3 DCA functions for priority species (n = 11 species) based all stop points (n = 1191) where ≥ 1 priority species (corrected detection probabilities) was present. Also shown is the significance value (*P*) of each correlation and % variance explained by the first 3 DCA axes.

	DCA 1		DCA 2		DCA 3	
	r	P	r	P	r	P
Landcover classes						
Cropland (ha)	0.204	< 0.001	0.437	< 0.001	0.057	0.049
Forage (ha)	-0.013	0.665	-0.061	0.034	-0.061	0.036
Native grasslands (ha)	-0.258	< 0.001	-0.403	< 0.001	-0.016	0.577
Tame pasture (ha)	0.008	0.784	-0.119	< 0.001	-0.034	0.238
Shrub (ha)	-0.109	0.000	-0.135	< 0.001	0.015	0.594
Trees (ha)	0.003	0.925	-0.038	0.192	0.014	0.625
Wetlands (ha)	0.120	< 0.001	-0.068	0.018	-0.029	0.321
Open waterbodies (ha)	0.162	< 0.001	-0.024	0.401	-0.014	0.626
Otherlands (ha)	0.029	0.325	0.056	0.053	-0.014	0.617
Mud/ sand/ saline (ha)	0.064	0.028	-0.069	0.017	-0.031	0.288
Landscape structure						
Heterogeneity index	0.037	0.196	-0.285	< 0.001	-0.069	0.017
Number of patches	-0.042	0.149	-0.177	< 0.001	-0.007	0.797
Mean patch size (ha)	-0.077	0.008	0.251	< 0.001	0.008	0.774
Mean core area (ha)	-0.075	0.010	0.250	< 0.001	0.079	0.007
Total edge (m)	-0.001	0.972	-0.211	< 0.001	-0.032	0.267
Number of native grasslands patches	-0.049	0.093	-0.188	< 0.001	-0.020	0.501
Mean native grassland (ha) patch size	-0.205	< 0.001	-0.328	< 0.001	-0.028	0.342
Mean native grassland core area (ha)	-0.155	< 0.001	-0.261	< 0.001	-0.036	0.214
% Variance explained	16.7		23.3		9.0	

Table B.8. Pearson's correlation coefficients (r) for 10 habitat classes and 9 landscape structure matrices with 3 DCA functions based on a randomly selected (50%) subset of stop points (n = 439) including all core species in low duck density stratum. Also shown is the significance value (*P*) of each correlation and % variance explained by the first 3 DCA axes.

	DCA 1		DCA 2		DCA 3	
	r	P	r	P	r	P
Landcover classes						
Cropland (ha)	-0.423	< 0.001	0.485	< 0.001	-0.170	< 0.001
Forage (ha)	0.136	0.004	-0.023	0.638	0.035	0.467
Native grasslands (ha)	0.341	< 0.001	-0.514	< 0.001	0.167	< 0.001
Tame pasture (ha)	0.084	0.080	-0.060	0.212	0.064	0.178
Shrub (ha)	0.276	< 0.001	-0.264	< 0.001	-0.133	0.005
Trees (ha)	0.152	0.001	-0.129	0.007	-0.014	0.762
Wetlands (ha)	0.141	0.003	0.057	0.231	-0.011	0.825
Open waterbodies (ha)	0.133	0.005	0.098	0.041	0.098	0.041
Otherlands (ha)	0.277	< 0.001	0.092	0.054	-0.041	0.396
Mud/ sand/ saline (ha)	0.080	0.096	-0.132	0.006	0.022	0.639
Landscape structure						
Heterogeneity index	0.500	< 0.001	-0.155	0.001	-0.036	0.453
Number of patches	0.380	< 0.001	-0.171	< 0.001	-0.117	0.014
Mean patch size (ha)	-0.546	< 0.001	0.146	0.002	0.044	0.354
Mean core area (ha)	-0.550	< 0.001	0.152	0.001	0.029	0.539
Total edge (m)	0.500	< 0.001	-0.155	0.001	-0.094	0.050
Number of native grasslands patches	0.283	< 0.001	-0.158	0.001	-0.102	0.032
Mean native grassland (ha) patch size	0.264	< 0.001	-0.455	< 0.001	0.205	< 0.001
Mean native grassland core area (ha)	0.177	< 0.001	-0.384	< 0.001	0.159	0.001
% Variance explained	28.2		21.1		6.9	

Table B.9. Pearson's correlation coefficients (r) for 10 habitat classes and 9 landscape structure matrices with 3 DCA functions based on a randomly selected (50%) subset of stop points (n = 951) including all core species in medium or high duck density strata. Also shown is the significance value (*P*) of each correlation and % variance explained by the first 3 DCA axes.

	DCA 1		DCA 2		DCA 3	
	r	P	r	P	r	P
Landcover classes						
Cropland (ha)	0.300	< 0.001	0.047	0.146	0.023	0.483
Forage (ha)	-0.096	0.003	-0.031	0.341	-0.002	0.945
Native grasslands (ha)	-0.384	< 0.001	-0.182	< 0.001	-0.007	0.831
Tame pasture (ha)	-0.019	0.555	0.121	< 0.001	-0.072	0.026
Shrub (ha)	-0.119	< 0.001	0.011	0.723	-0.023	0.486
Trees (ha)	0.041	0.204	0.143	< 0.001	-0.049	0.133
Wetlands (ha)	0.243	< 0.001	0.122	< 0.001	0.146	< 0.001
Open waterbodies (ha)	0.263	< 0.001	0.143	< 0.001	0.055	0.088
Otherlands (ha)	-0.095	0.003	0.403	< 0.001	-0.276	0.000
Mud/ sand/ saline (ha)	0.075	0.020	0.036	0.261	0.034	0.299
Landscape structure						
Heterogeneity index	0.034	0.290	0.275	< 0.001	-0.059	0.070
Number of patches	0.016	0.623	0.087	0.007	0.023	0.469
Mean patch size (ha)	-0.150	< 0.001	-0.268	< 0.001	0.017	0.596
Mean core area (ha)	-0.104	0.001	-0.302	< 0.001	0.030	0.358
Total edge (m)	0.060	0.064	0.176	< 0.001	0.008	0.803
Number of native grasslands patches	-0.036	0.261	0.020	0.537	0.005	0.881
Mean native grassland (ha) patch size	-0.346	< 0.001	-0.189	< 0.001	-0.014	0.675
Mean native grassland core area (ha)	-0.297	< 0.001	-0.201	< 0.001	-0.009	0.772
% Variance explained	25.5		10.1		4.2	

Table B.10. Comparisons of mean priority species richness and relative abundance; and mean relative abundance of subset of grassland obligates among stops containing large, contiguous patches of native prairie, large parcels of patchy native prairie and remnant patches of native prairie. Stop-level relative abundance of all priority species except northern harrier and Swainson's hawk were corrected for detection probabilities. Also shown are number of stops (n), and 95% confidence limits (lower and upper).

		Species richness of priority group		Relative abundance of priority group		Relative abundance of grassland obligates[a]	
	n	mean		mean		mean	
Large patches of contiguous native grassland[b]	161	1.82	(1.59 - 2.05)	9.77	(8.14 - 11.39)	5.77	(4.65 - 6.89)
Large patches of patchy native grassland[c]	113	1.66	(1.44 - 1.88)	7.16	(5.98 - 8.33)	4.04	(3.29 - 4.78)
Remnant native grassland patches[d]	287	0.55	(0.45 - 0.65)	2.14	(1.67 - 2.61)	0.86	(0.64 - 1.08)

a Grassland obligates are priority species that use primarily native grassland habitats: chestnut-collared longspur, grasshopper sparrow, Le Conte's sparrow (2001 only), lark bunting, northern harrier, Sprague's pipit, and Swainson's hawk (Vickery et al. 1999).

b Contiguous native grassland habitat refers to stops containing ≥ 30 ha native grasslands; ≤ 3 ha of wetlands, waterbodies or shrub and ≤ 3 native patches.

c Patchy native grassland habitat refers to stops containing ≥ 30 ha native grasslands; ≥ 3 ha of wetlands, waterbodies or shrub.

d Remnant native grassland habitat refers to stops containing ≤ 10 ha native grasslands and ≤ 3 native patches.

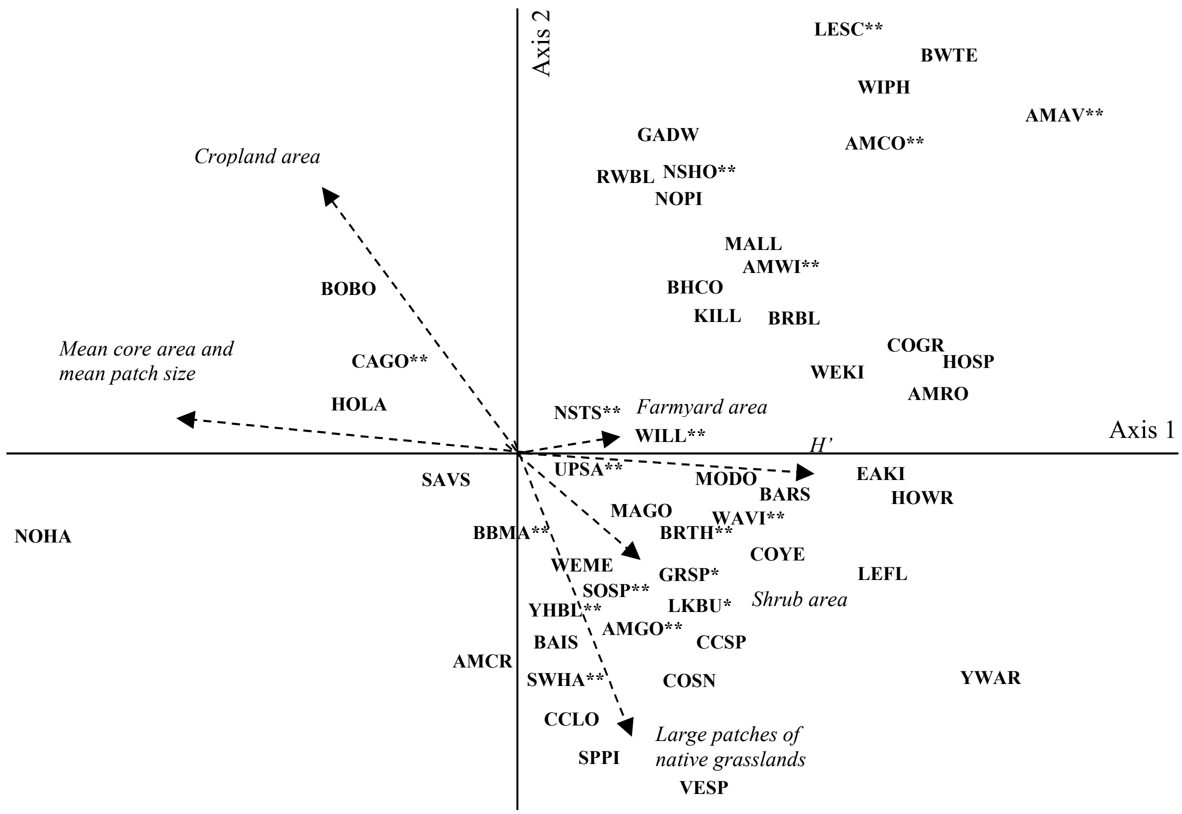

Figure B.1. DCA based on species-level bird abundance data (n = 48 species) obtained from a random sample of 50 % of all unique 2001 and 2002 survey stop points (n = 432) in low duck density stratum. AOU codes for each species are given in Appendix B, Table B.2. All species are strongly associated (P < 0.01) with at least one of two principle DCA functions except species with single* are significantly correlated (P < 0.05) and species with double ** are not.

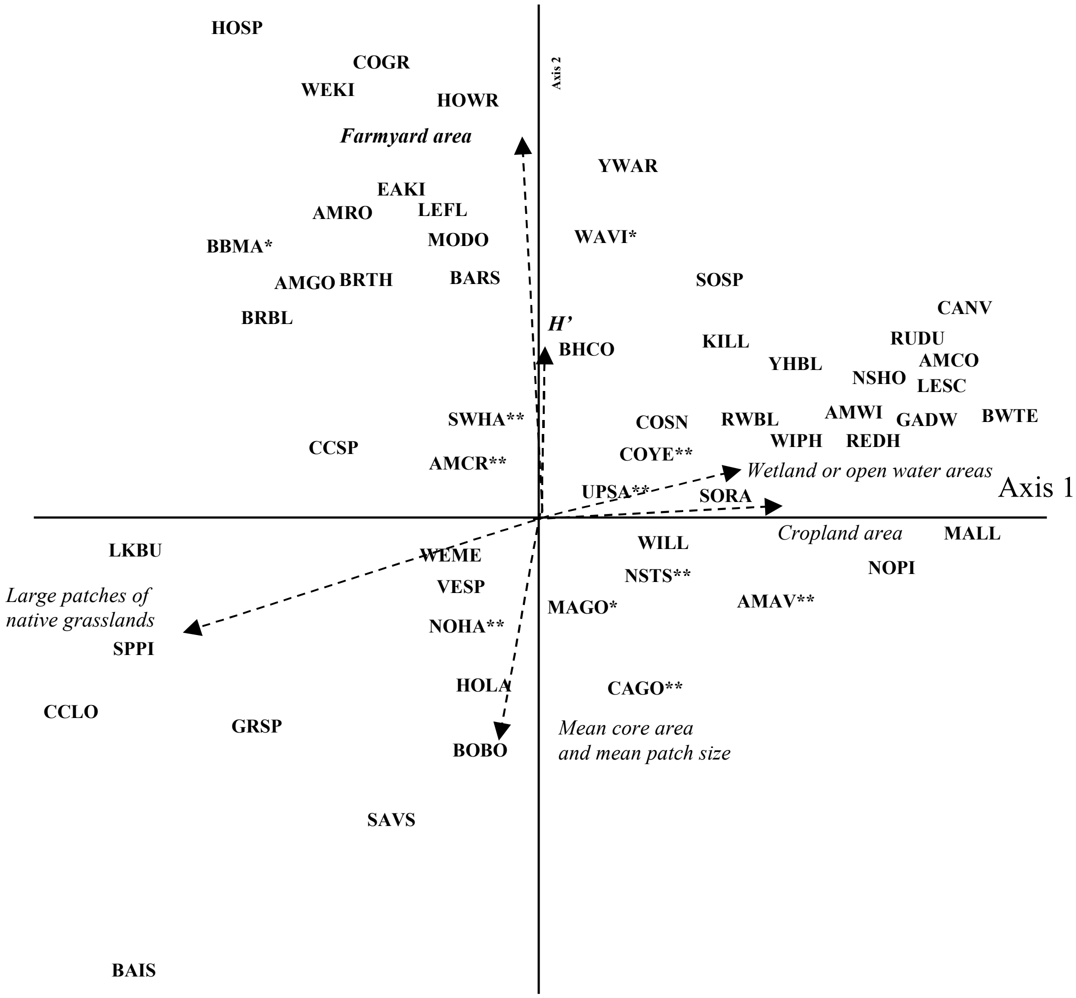

Figure B.2. DCA based on species-level bird abundance data (n = 55 species) obtained from a random sample of 50 % of all unique 2001 and 2002 survey stop points (n = 951) in medium or high duck density strata. AOU codes for each species are given in Appendix B, Table B.2. All species are strongly associated (P < 0.01) with at least one of two principle DCA functions except species with single* are significantly correlated (P < 0.05) and species with double ** are not.